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GROUND-WATER MODELING OF IMPACTS OF PROPOSED SPRAY IRRIGATION

PREPARED FOR

ROCKWELL INTERNATIONAL
ROCKY FLATS FACILITY
GOLDEN, COLORADO

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1.0 INTRODUCTION

Rockwell International (Rockwell), operator of the United States Department of Energy Rocky Flats Facility, contracted with S.S. Papadopulos and Associates, Inc. (SSP&A) to undertake an assessment of the impacts of proposed spray irrigation on the ground-water flow systems at the facility. The specific scope of service was to estimate the impacts to the water table, as well as to ground-water flow directions, from spray irrigating 80 million gallons per year (220,000 gallons per day) of tertiary treated sewage effluent. Two candidate locations were selected by Rocky Flats personnel for possible irrigation sites. These two potential sites are located on Figure 1. They have been arbitrarily designated by SSP&A as Areas 1 and 2. Rockwell initially proposed to irrigate 40 acres in each area; however, both areas could be expanded to approximately 120 acres.

The ground-water assessment performed by SSP&A used an analytical ground-water flow model to make quantitative analyses of each site. The analytical solution was used to calculate the changes in the elevation of the water table (hydraulic head) through time. With this analytical model, which used field data generated by Rockwell contractors, several application scenarios were modeled.

2.0 HYDROGEOLOGIC BACKGROUND AND SETTING

Rockwell International has undertaken, and continues to undertake, extensive geologic and hydrogeologic studies of the facility. In 1986 and 1987 approximately 107 ground-water observation wells were installed. Aquifer tests were conducted on several of these wells, and estimates of the hydraulic conductivities (or permeabilities) of the geologic materials were made from the test data collected.

Extensive geologic mapping of the facility has also taken place. At the locations of the two proposed spray irrigation fields the geology consists of Rocky Flats Alluvium overlying steeply dipping beds of the Arapahoe Formation. The Rocky Flats Alluvium consists of clayey or silty gravel. In the two areas of interest, the upper one foot of the Rocky Flats Alluvium consists of very gravelly sandy loams and very gravelly clays from a depth interval of one to four feet. Below a depth of four feet the alluvium is primarily a clayey or silty gravel. The Arapahoe Formation is primarily a claystone or siltstone interbedded with sandstone.

There are no wells located within the areas of the proposed irrigation fields, and therefore geologic and hydrogeologic information had to be extrapolated from other areas. In November, 1986, Hydro-Search, Inc., under contract to Rockwell, produced a contour map of the water table, a geologic map of bedrock, and a contour map of the top of the bedrock surface. Data from these maps and thicknesses of the alluvium were used to produce a contour map of the thickness of the saturated alluvium materials (Figure 1). In Area 1, the saturated alluvium ranges in thickness from 28 to 36 feet, and the average saturated thickness is approximately 32 feet. In Area 2, the average saturated thickness is about 22 feet. Variations of a few feet in the estimated saturated thickness had little impact on the conclusions of this study.

Ground-water flow directions and gradients were determined using the water-level data contained in Appendix E-10 of Volume VII of the Part B

Operating Permit Application. In Area 1, the flow direction was calculated by using the water levels measured in Wells 47-86, 45-86 and 10-86 on October 13, 1986 (Figure 1). The calculated flow direction for Area 1 is in a northeast direction (Figure 2). The hydraulic gradient was calculated to be 0.0072 feet per foot (ft/ft).

Only one well exists in the vicinity of Area 2 (Figure 1), and thus the ground-flow direction and hydraulic gradient were estimated for this area. On the surficial geology map (produced by Hydro-Search, Inc.) of the facility, springs were noted east of the proposed irrigation field near the alluvium/bedrock contact. A hydraulic gradient of 0.0017 ft/ft was calculated using the elevation of these springs with the water-level elevation measured in Well 55-86 on October 13, 1986. Based on previous studies for the facility (Hurr, 1976) it was assumed that the ground-water flow direction was from west to east.

Hydrogeologic testing of the observations wells at Rocky Flats was undertaken by Chen and Associates, Inc., and Hydro-Search, Inc. to estimate the hydraulic conductivities of the geologic materials in the region. Chen and Associates, Inc. reported that the hydraulic conductivity of the Rocky Flats Alluvium ranged from 4.9×10^{-5} centimeters per second (cm/s) to 5.8×10^{-6} cm/s. Hydro-Search reported a range of hydraulic conductivity values for the alluvial materials from 1×10^{-5} cm/s to 9×10^{-5} cm/s. From both of these investigations it was found that the hydraulic conductivities of the alluvium are relatively low. Even though the percentage of gravel in the alluvium is relatively high, the silt and clay content is sufficient to reduce significantly the hydraulic conductivities. A range of hydraulic conductivities of 1 x 10^{-4} cm/s (0.28 feet per day) to 1 x 10^{-5} cm/s (0.028 feet per day) was used for these analyses. The range covers the limits of the hydraulic conductivities calculated by Hydro-Search and Chen and Associates.

3.0 MODELING APPROACH

An analytical model was developed to calculate the changes in water levels that would occur with time due to recharge after reviewing the existing data base for the facility. An analytical method was used in preference to a numerical approach for two reasons which are discussed below.

First, each potential recharge area appears to be hydrologically separated from the main facility. This observation is based upon a review of the water-table map and field observations. It is assumed that water applied in Area 1 would discharge north into Rock Creek or south into McKay Ditch. In Area 2 recharge water would probably discharge at the contact between alluvium and colluvium and move as overland flow to Woman Creek. Based on these observations, it was judge that a numerical model of the entire site was not necessary and an analytical model of each separate recharge areas was appropriate.

Second, an analytical model was used because the amount of data for each proposed recharge area are limited. Data on saturated thickness, hydraulic conductivity, storage coefficient and ground-water flow direction and gradient are limited. With these limited data, a numerical approach is not warranted because broad hydrogeologic assumptions would have to be made about the conditions at each node. An analytical approach assumes isotropic and homogeneous conditions which probably do not exist at the site. However, the analytical model can provide insight into the range of results caused by variations in the input parameters, such as the hydraulic conductivity and storage coefficient. Also, if the analysis using an analytical model showed decisively that spray irrigation was, or was not, feasible, then a refinement of the approach using numerical techniques would not be necessary.

The specific analytical solution chosen analyzes the growth of a ground-water mound in a water-table (unconfined) aquifer due to surface recharge from a circular basin. This type of problem was solved by Hantush (1967) and details of the method are contained in Appendix A. A Fortran language computer model for this analytical solution was developed by SSP&A based upon a program presented in Walton (1984).

The rectangular irrigation fields into which Rockwell is proposing to discharge their treated water were simulated in the model by approximating the rectangular areas with circular recharge basins. For Area 1, two circular basins were used, each with a radius of 500 feet (Figure 2). The total recharge surface area for these two basins is approximately 36 acres. In Area 2, the proposed recharge area was simulated with ten circular recharge basins, each with a radius of 210 feet (Figure 3). The total surface area modeled using the ten basins is 32 acres.

One of the basic assumptions of the modeling analysis was that the water used for irrigation is capable of infiltrating and percolating to the water table. This assumption may not be completely true because of the geologic conditions at the sites. The clayey soil horizon encountered at a depth of one foot may reduce the amount of percolation to the water table. The model also assumes that the lower part of the water-table aquifer is bounded by an aquitard. This assumption is satisfied at Rocky Flats because the hydraulic conductivities of the Rocky Flats Alluvium is generally one to two orders of magnitude greater than that of the Arapahoe Formation. This hydraulic conductivity contrast causes ground-water flow to move predominantly in the alluvium rather than in the Arapahoe Formation.

The model was originally used to calculate the change in saturated alluvial thickness or the rise in the water table. This situation was modeled for a variety of input parameters for both areas. The model was then modified to calculate the water table elevation in the vicinity of the recharge areas.

The input parameters for the analytical model are the hydraulic conductivity, storage coefficient, recharge rate and aquifer thickness. The storage coefficient was selected to be 0.07. This value reflects the fact that the gravel contains a significant amount of clay. The storage coefficient only affects the time period necessary to reach steady state, and does not impact the overall conclusions of the study.

The impacts of expanding the size of the area experiencing recharge was modeled by reducing the application rate to the existing number of basins. For example, in Area 1, the impacts of discharging 45 million gallons per year of water to an area of 108 acres was modeled by reducing the recharge rate of 0.01 feet per day (ft/d) to 0.0035 ft/d.

4.0 RESULTS

4.1 AREA 1

Twelve different scenarios were modeled for Area 1. These scenarios are summarized in Table 1. The approach was to simulate the range of realistic possible combinations of hydraulic conductivities and recharge rates. The range of hydraulic conductivities used was 0.028 to 0.28 ft/d, and the range of recharge rates used was 0.0012 to 0.01 ft/d, which represent applications of 15 and 45 million gallons per day, respectively. Calculations were made for three and ten years. Cases 1 through 4 for Area 1 were modeled assuming that 45 million gallons of water would be recharged to the water table per year. This recharge rate was distributed over 36 acres in these four cases. The recharge rate of 45 million gallons per year was supplied to SSP&A by Rockwell. This volume of recharge assumes that 35 million gallons per year would be evaporated or transpired of the total 80 million gallons per year to be applied. Cases 5 through 9 assume that the 45 million gallons per year of potential recharge water is sprayed over an area of 108 acres.

In cases 2, 7 and 9 where the time of application was ten years, the water-table mound caused by the recharge had reached or exceeded the elevation of the land surface. In these cases, the model continued to add recharge to the system even though the elevation of the calculated water table may have been above the elevation of the land surface. The interpretation of this situation is that the applied water moves off the site as overland flow. In the last column of Table 1, it is noted whether overland flow was occurring. This assessment was made by superimposing the calculated water-table map, which had been impacted by recharge, on the land surface topography. If the water table had a greater elevation than the land surface, then overland flow would occur. The maps for all the computer runs are contained in Appendix B, and they can be overlain on the topographic maps in Figures 2 and 3 by aligning the axes.

Cases 10 and 11 were modeled assuming relatively low recharge rates. In these two cases it was assumed that the amount of recharge would be only 15 million gallons per year and that the remaining 65 million gallons would be lost to evaporation. A value of 12 million gallons per year was provided to SSP&A by Rockwell as a minimum amount of total recharge. It was also assumed that the recharge area would be approximately 108 acres and that the hydraulic conductivity would be 0.14 ft/d (5×10^{-5} cm/s). This estimate of hydraulic conductivity is an approximate mean value based upon hydraulic conductivity data obtained from the RCRA Part B Application and the work performed by Chen and Associates. Cases 10 and 11 were modeled for three and ten years, respectively, and the results show that the calculated water levels are below the land surface. Based upon subsequent discussions with Rockwell, the minimum amount of recharge is probably closer to 45 million gallons per year. If this is true, then spray irrigation of the entire 45 million gallons per year in this area does not appear to be feasible because of overland flow.

SSP&A was requested by Rockwell to estimate the maximum amount of recharge which would occur in each area without overland flow. The maximum amount of recharge was calculated to be about 20 million gallons per year. Case 12 simulates the application of 20 million gallons per year over an area of 108 acres. After ten years at this rate of recharge no overland flow occurred in the spray irrigated areas.

4.2 AREA 2

As previously mentioned, the modeling of Area 2 required the use of ten recharge basins each with a radius of 210 feet. The mean saturated thickness of the alluvium for this area was estimated to be 22 feet, which is based upon the geologic log and a water level measured on October 13, 1986 in Well 55-86.

Nine different cases were modeled for the area by varying the recharge rates and hydraulic conductivities. These nine cases are summarized in Table 1. The range of hydraulic conductivities used in the simulations is the same as that used for the modeling of Area 1. In Cases 1 through 4 it was assumed that 45 million gallons of water per year would be applied to a land area of 96 acres. In Cases 5 and 6, 45 million gallons of water per year would be applied to a land area of 32 acres. In Cases 7 and 8 it was assumed that the recharge rate would be 15 million gallons per year over an expanded recharge area of 127 acres. For Cases 7 and 8 the assumed hydraulic conductivity was 0.14 ft/d (5 x 10^{-5} cm/s).

In the first six cases, overland flow would occur within three years of operation of the system. In Case 7, after three years of operation, some localized overland flow occurs as a result of the water table's proximity to the land surface. In Case 8, which represents the impacts after ten years of recharge, most of the recharge area is experiencing overland flow because the water table has reached the land surface. In conclusion, Area 2 is not an appropriate site for spray irrigation if overland flow is to be avoided, even if the recharge volume is only 15 million gallons per year spread over 127 acres.

Case 9 was modeled to estimate the maximum amount of recharge which could be applied such that overland flow was avoided. The maximum recharge rate was calculated to be about 4.5 million gallons per year. Under this scenario, no overland flow occurs in the spray irrigated area after 10 years of operation.

5.0 SUMMARY AND CONCLUSIONS

SSP&A was contracted by Rockwell to model and assess the impacts of proposed spray irrigation schemes on ground water at two different locations at the Rocky Flats facility. SSP&A developed a computer model of each proposed recharge area. The model incorporated an analytical solution which was developed by Hantush (1967). The major input parameters to the model are hydraulic conductivity, storage coefficient, recharge rate, saturated thickness and size of the recharge area. The model calculates the rise of the water table due to recharge for a selected time interval. Twelve different scenarios were modeled for Area 1, while nine were modeled for Area 2, covering the entire range of input parameters expected. In all cases where the 45 million gallons per year of recharge lasted longer than three years, the water table reached the land surface and overland flow occurred.

SSP&A was also requested by Rockwell to estimate the maximum amount of water which could be recharged in each area without having overland flow. Assuming a hydraulic conductivity of 5×10^{-5} cm/s (0.14 ft/d) for the alluvium and an application period of 10 years, the maximum estimated recharge rate for Area 1 is about 20 million gallons per year and for Area 2 it is estimated to be about 15 million gallons per year.

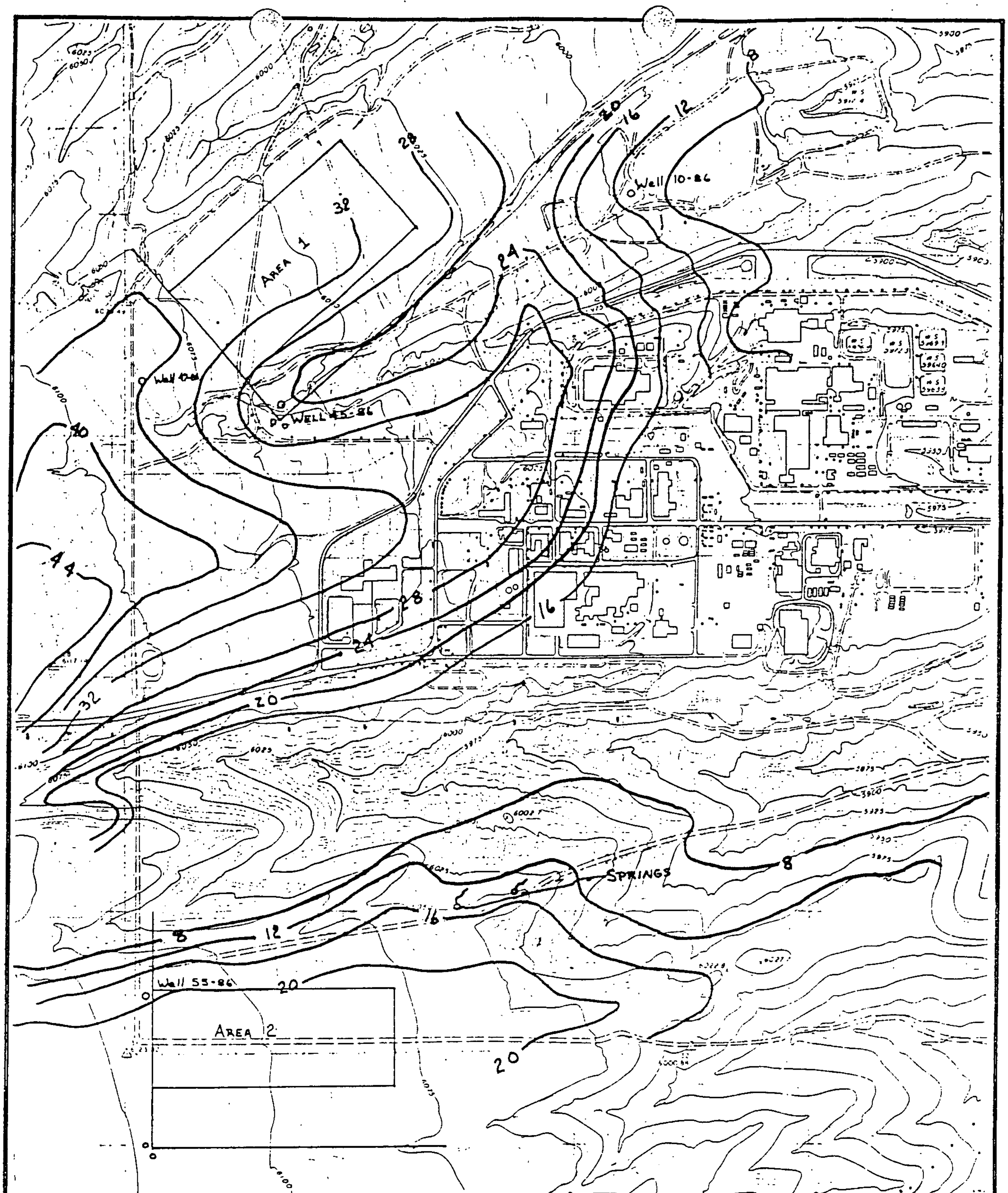
It is recommended that alternatives to spray irrigation be investigated, or that only a fraction of the 80 million gallons of treated sanitary waste water be spray irrigated.

6.0 REFERENCES

Hantush, M. S., 1967, Growth and Decay of Groundwater-Mounds in Response to Uniform Percolation: Water Resources Research, vol. 3, no. 1, pp. 227-234.

Hurr, R. T., 1976, Hydrology of a Nuclear-Processing Plant Site, Rocky Flats, Jefferson County, Colorado: U.S. Geological Survey Open-File Report 76-268, 68 p.

Walton, W. C., 1984, Flow, Mass and Heat Transport and Subsidence, Analytical and Computer Models: National Water Well Association, 566 p.

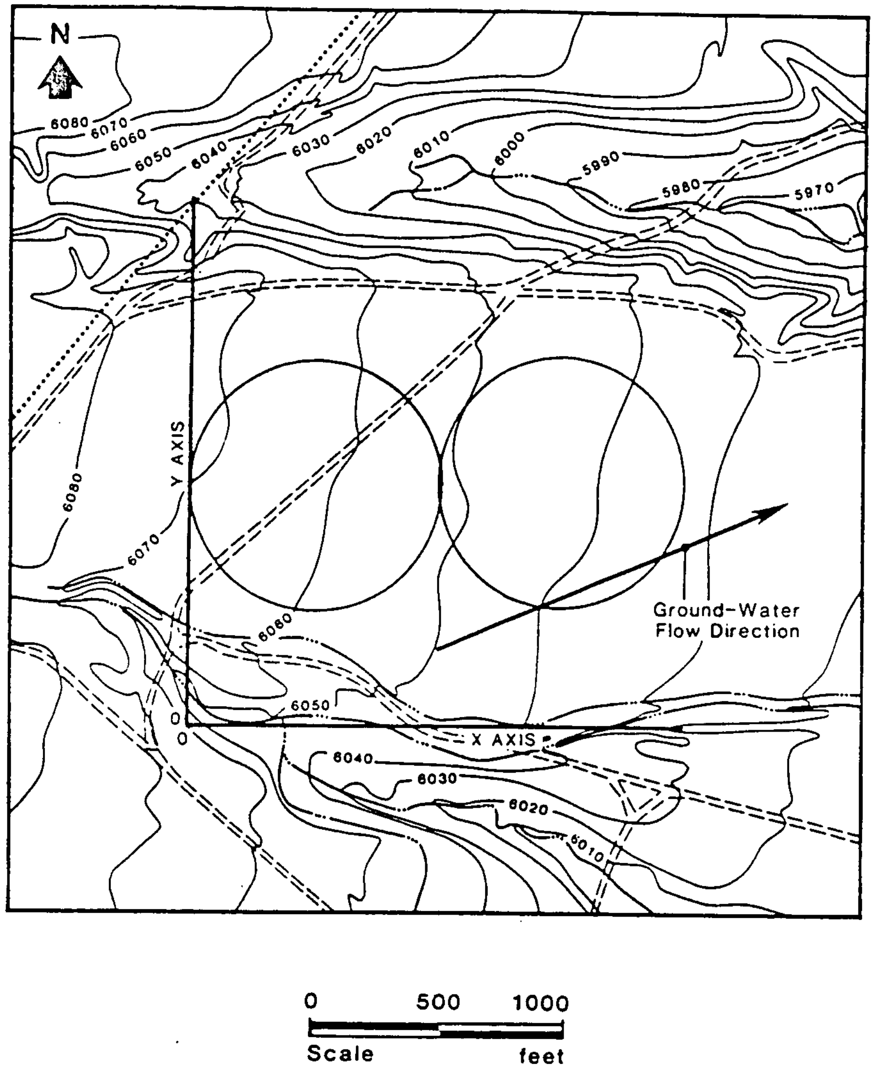


EXPLANATION

—20— Contour of thickness of saturated Alluvium / Colluvium.
Contour interval : 4'. Water levels measured 10-13-86

○ Well location

S. S. PAPADOPULOS & ASSOCIATES, INC. CONSULTING GROUND WATER HYDROLOGISTS	LOCATIONS OF PROPOSED SPRAY IRRIGATION FIELDS AND THICKNESS OF SATURATED ALLUVIAL / COLLUVIAL MATERIALS	FIGURE 1



EXPLANATION

—5980— Line of equal elevation, in feet above MSL

Road

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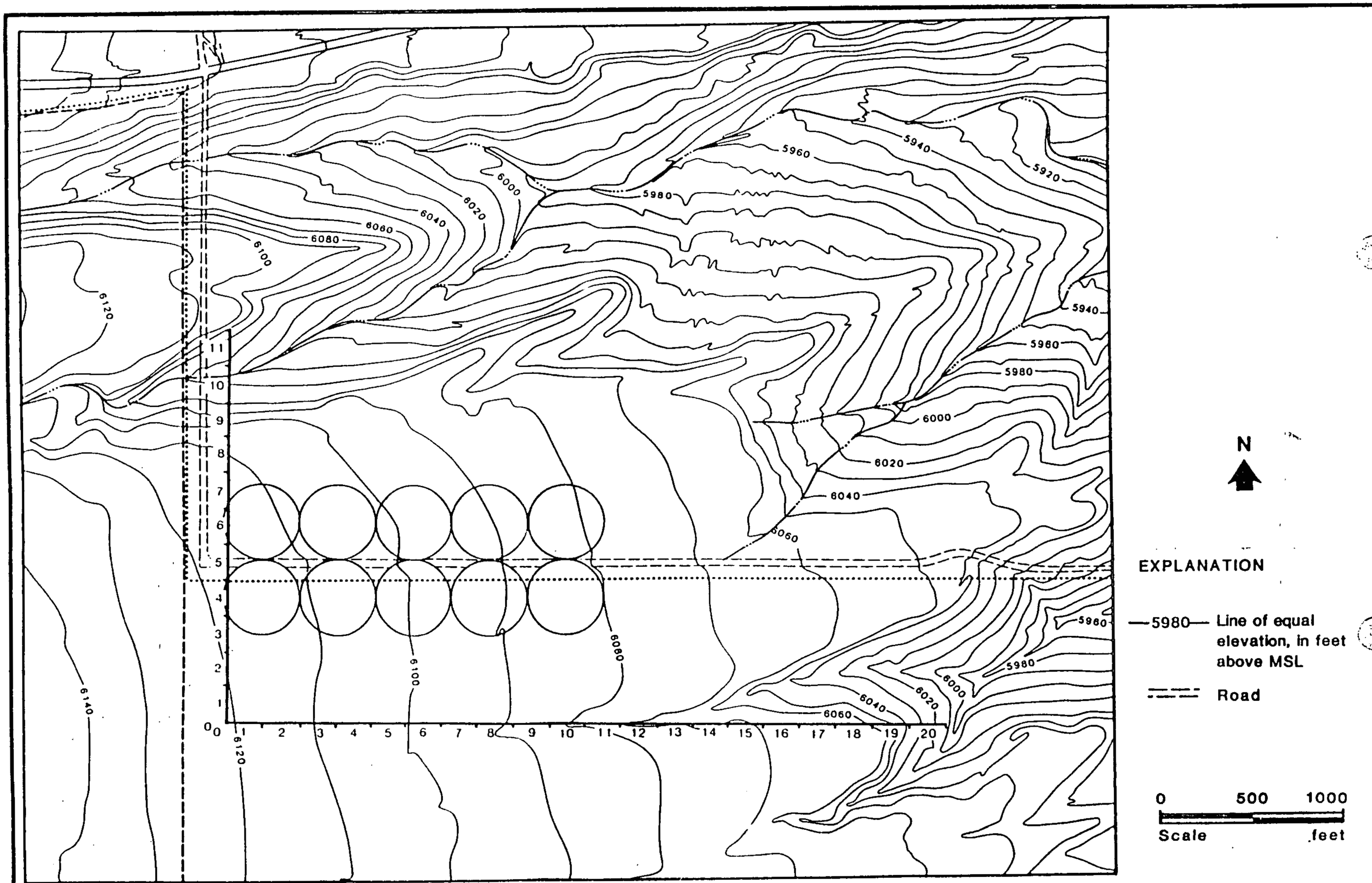
PROPOSED RECHARGE AREA 1

FIGURE 2



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PROPOSED RECHARGE AREA 2

FIGURE 3

TABLE 1

CASES MODELED FOR SPRAY IRRIGATION EVALUATION

Case	Hydraulic Conductivity (ft/d)	Recharge Area (acres)	Total Recharge 10^6 gal/yr	Recharge Rate (ft/d)	Time Modeled (years)	Conclusion
AREA 1						
1	0.28	36	45	0.01	1	Local overland flow
2	0.28	36	45	0.01	10	Overland flow
3	0.028	36	45	0.01	1	Local overland flow
4	0.028	36	45	0.01	3	Overland flow
5	0.028	108	45	0.0035	1	No overland flow
6	0.028	108	45	0.0035	3	No overland flow
7	0.028	108	45	0.0035	10	Overland flow
8	0.28	108	45	0.0035	3	No overland flow
9	0.28	108	45	0.0035	10	Local overland flow
10	0.14	108	15	0.0012	3	No overland flow
11	0.14	108	15	0.0012	10	No overland flow
12	0.14	108	20	0.0016	10	No overland flow
AREA 2						
1	0.028	96	45	0.004	3	Overland flow
2	0.028	96	45	0.004	10	" "
3	0.28	96	45	0.004	3	" "
4	0.28	96	45	0.004	10	" "
5	0.28	32	45	0.012	3	" "
6	0.28	32	45	0.012	10	" "
7	0.14	127	15	0.001	3	Local overland flow
8	0.14	127	15	0.001	10	Overland flow
9	0.14	127	4.5	0.0003	10	No overland flow

APPENDIX A

Discussion of Model

The computer model used for the analysis of the impacts of spray irrigation was based on an analytical technique developed by Hantush (1967). Hantush specifically derived equations for the solution of a boundary value problem which dealt with growth and decay of ground-water mounds in response to uniform percolation.

The solution of this problem takes on two forms. One form is for the case where the radius from the center of the recharge basin to the point of observation is less than the radius of the recharge basin. The other is for the case where the distance to the point of observation is greater than the radius of the recharge basin.

A BASIC language program to solve these equations was developed by Walton (1984), and was obtained for this study from the International Ground-Water Modeling Center, an institute which receives funding support from the U.S. Environmental Protection Agency. This program was modified by SSP&A and converted to Fortran. The capability to have multiple recharge basins was added to the code. Ground-water discharge to the streams and/or ditches was simulated with imaginary withdrawal basins placed on the opposite side of the stream. These imaginary basins were located at an equal distance from the stream as were the real recharge basins.

A grid generating subroutine was also added to the model so that the head values could be calculated at each grid point. The values of head at each grid point could then be contoured using Golden Software's TOPO program.

Program Listing

```
C
C     PROGRAM WRITTEN BY R. STERRETT AND C. ANDREWS OF SSP&A, NOVEMBER 1987 TO
C     SOLVE ANALYTICAL CIRCULAR RECHARGE PROBLEM USING HANTUSH METHOD (1967)
C
C     ANALYTICAL SOLUTION ADOPTED FROM WALTON (1984) AND IGWMC PROGRAM
C
C
C     THE INPUT DATA FILE IS DEFINED TO BE  'SSLEAK.DAT'
C        THE FORMAT OF THE DATA FILE IS AS FOLLOWS:
C           LINE 1    XMIN,XMAX,DX,YMIN,YMAX,DY   (DEFINES SOLUTION GRID)
C           LINE 2    PH,BM,S,RM,HI,T     (PERMEABILITY,SAT  THICK,SPECIFIC
C                                           YIELD,RADIUS OF RECHARGE,INITIAL
C                                           HEAD,SOLUTION TIME --ALL IN
C                                           FEET--DAY UNITS)
C           LINE 3    NWELLS              (# OF WELLS)
C
C           LINE 4+   XW,YW,Q             (X,Y COORDINATES OF WELL AND
C                                          RECHARGE RATE    FEET-DAY UNITS)
CC
       PARAMETER (KW=50,NP=10,NC=53,NR=48)
C                KW=# OF WELLS
C                NC=# OF COLUMNS IN SOLUTION GRID
C                NR=# OF ROWS IN SOLUTION GRID
C
C
C
        REAL XW(KW),YW(KW),QW(KW),P(NP)
        REAL L,KO
        DIMENSION HH(200,200)
        SAVE
          OPEN(UNIT=10,FILE='SSLEAK.DAT')
          OPEN(UNIT=11,FILE='SSLEAK.GRD')
          READ(10,*) XMIN,XMAX,DX,YMIN,YMAX,DY
          WRITE(*,*) XMIN,XMAX,DX,YMIN,YMAX,DY
          IO=INT(XMIN/DX)
          II=INT(XMAX/DX)
C         IMAX=II-IO+1
C         IMIN=1
          JO=INT(YMIN/DY)
          JJ=INT(YMAX/DY)
C         JMAX=JJ-JO+1
C         JMIN=1
          READ(10,*) PH,BM,S,RM,HI,T
          WRITE(*,*) PH,BM,S,RM,HI,T
          READ(10,*) NWELL
          DO 790 M=1,NWELL
             READ(10,*) XW(M),YW(M),QW(M)
  790     CONTINUE
```

```
C
C.. GO THROUGH GRID
       IQ=0
       DO 100 I=I0,II
        IQ=IQ+1
        WRITE(*,*) I
        JQ=0
        DO 100 J=J0,JJ
        JQ=JQ+1
        X=I*DX
        Y=J*DY
        H=0
        DO 810 NN=1,NWELL
           R=SQRT((X-XW(NN))**2 + (Y-YW(NN))**2)
        WR=QW(NN)
        CALL CIRC(R,PH,BM,S,RM,WR,HI,T,HM)
        H=H+HM-HI
  810   CONTINUE
C
C       THE FOLLOWING LINE OF CODE IS MODIFIED FOR SOLUTION TYPE
C       USE THE FOLLOWING EQUATIONS:
C
C          GENERAL PROBLEM      HH(IQ,JQ)=H+HI
C          AREA 1               HH(IQ,JQ)=H+6028-.00862*X-.00358*Y
C          AREA 2               HH(IQ,JQ)=H+6121-.0215*X-.00702*Y
C
C
C
            HH(IQ,JQ)=H+6121-.0215*X-.00702*Y
            WRITE(*,*) IQ,JQ,H
  100   CONTINUE
        CALL  GRID(HH,IQ,JQ,DX,DY)
        END
C
C
      SUBROUTINE CIRC(R,PHC,M,S,RM,RRC,HI,Z0,HM)
      REAL*4 M
      SAVE
      U0 = (RM**2)*S/(4*PHC*M*Z0)
       U1 = (R**2)*S/(4*PHC*M*Z0)
       IF( R.GE.RM)  GOTO 11700
       U  = U0
       CALL  WX(U,WU)
       HM = (RRC*(RM**2)/(2*PHC)*(WU-(R/RM)**2*EXP(-U0)+(1-EXP(-U0))
     *    /U0)+(HI**2))**.5
       GOTO 11730
11700  U  = U1
          CALL  WX(U,WU)
        HM = (RRC*(RM**2)/(2*PHC)*(WU+.5*U0*EXP(-U1))+HI**2)**.5
11730   RETURN
        END
        SUBROUTINE WX(U,WU)
```

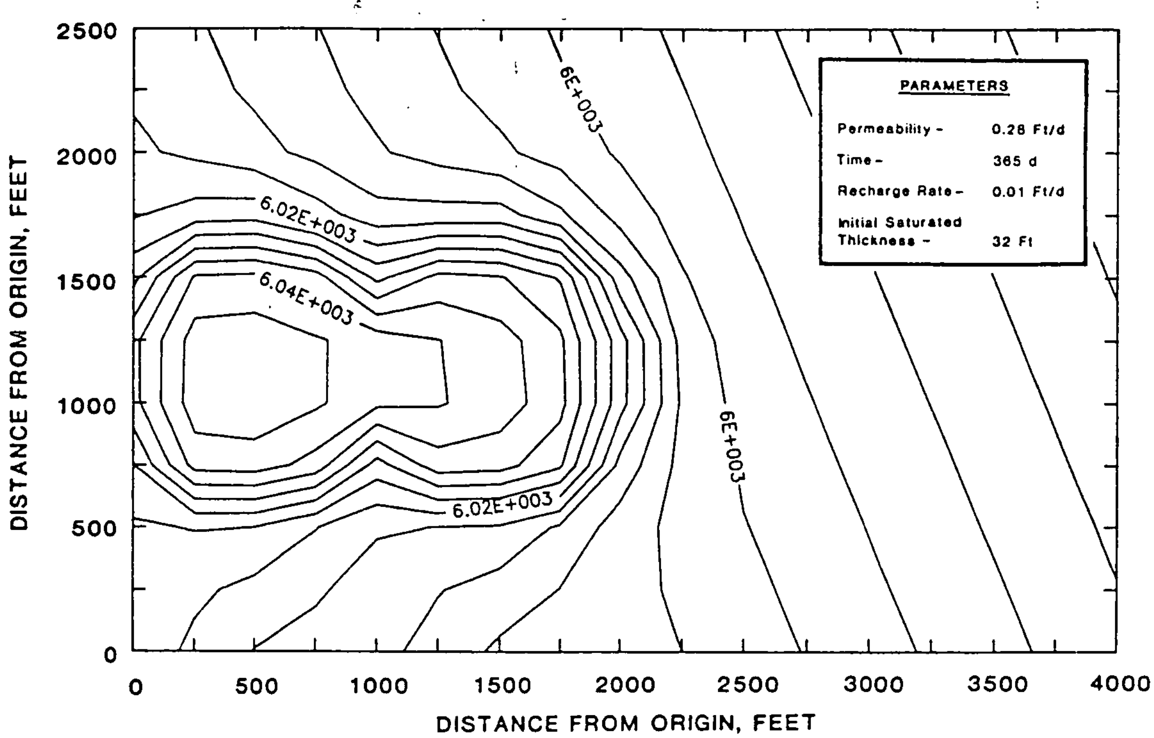
```
      REAL*8 MH,NH,A1,A2,A3,A4
      SAVE
      IF (U.GT.1) GOTO 2570
      A1=.5772156600000009
      A2=+.9999919300000017*U
      A3=.24991055*U**2
      W  = -LOG(U)-A1+A2-A3
      WU = W+.05519968*U**3-9.76004E-03*U**4+1.07857E-03*U**5
      RETURN
2570  CONTINUE
      A1=+8.573328740100034*U**3
      A2=+18.059016973*U**2
      A3= +8.634760892499999*U
      MH=U**4+A1+A2+A3
      A1=+.2677737343000013
      MH = MH+A1
      A1 = +9.573322345400009*U**3
      A2=+25.6329561486*U**2
      A3=+21.096530827*U
      A4 = +3.958496922800013
      NH=U**4+A1+A2+A3+A4
      WU = MH/(NH*U*EXP(U))
      RETURN
      END
     SUBROUTINE GRID(HD,IQ,JQ,DX,DY)
     INTEGER*4 I1,I2
     CHARACTER*4 DSPM
     DIMENSION HD(200,200)
      REAL*4 TIME,HDS,DELTAX,DELTAY
     REAL*8 XMIN,XMAX,YMIN,YMAX,HMIN,HMAX
     SAVE
     DATA DSPM /'DSAA'/
     OPEN (7,FILE='NULL.GRD ',STATUS='NEW',ACCESS='SEQUENTIAL',
    1      FORM='FORMATTED')
     NX1=1
     NX2=IQ
     NY1=1
     NY2=JQ
     NX=ABS(NX2-NX1)+1
     NY=ABS(NY2-NY1)+1
     DELTAX=DX
     DELTAY=DY
     XMIN=0
     YMIN=0
     XMAX=(NX-1)*DELTAX
     YMAX=(NY-1)*DELTAY
C    Determine hmin and hmax
     HMIN=9999999
     HMAX=-9999999

     DO 20 IX=NX1,NX2
       DO 10 IY=NY1,NY2
```

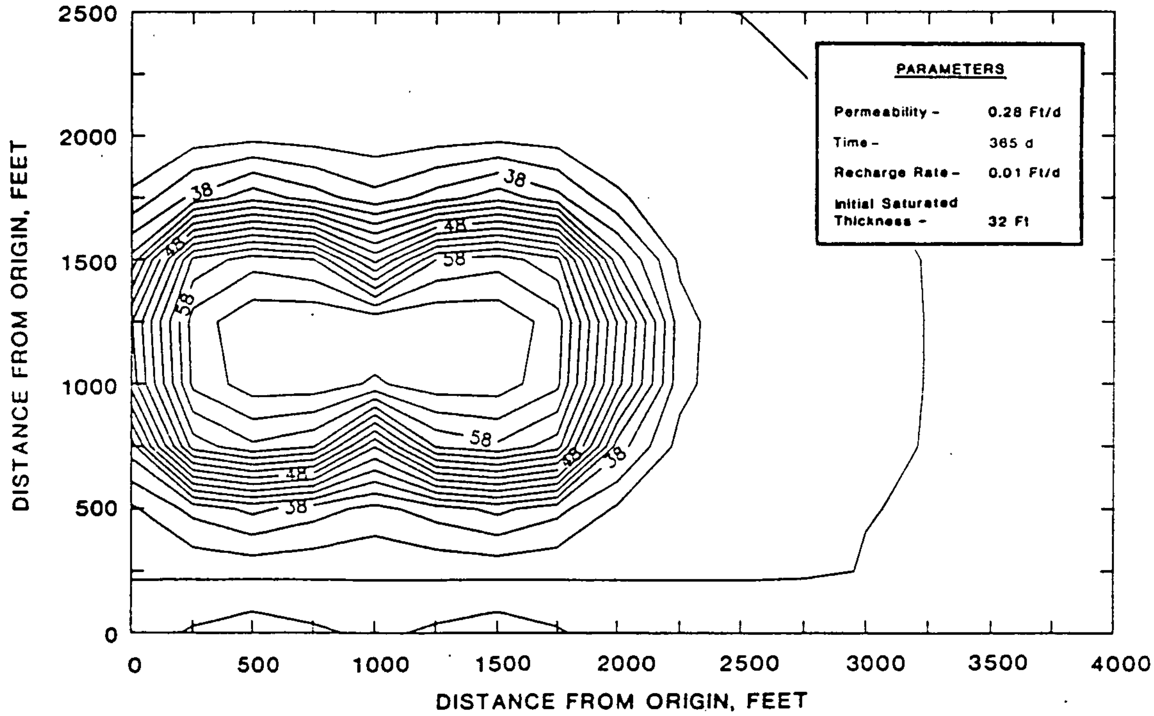
```
            IF (HD(IX,IY).LT.HMIN) HMIN=HD(IX,IY)
            IF (HD(IX,IY).GT.HMAX) HMAX=HD(IX,IY)
10        CONTINUE
20      CONTINUE
        WRITE(7,900)DSPM
  900   FORMAT(A4)
        WRITE(7,*)NX,NY,XMIN,XMAX,YMIN,YMAX,HMIN,HMAX
        WRITE(*,*)DSPM,NX,NY,XMIN,XMAX,YMIN,YMAX,HMIN,HMAX
        DO 40 KY=NY1,NY2
           DO 30 KX=NX1,NX2
             WRITE(7,*) HD(KX,KY)
C              WRITE(8,*) HD(KX,KY)
30         CONTINUE
40      CONTINUE

        CLOSE(7)
        END
```

LIST OF FIGURES -- APPENDIX B



a.) Calculated water-table elevation at 365 days.



b.) Calculated saturated thickness at 365 days

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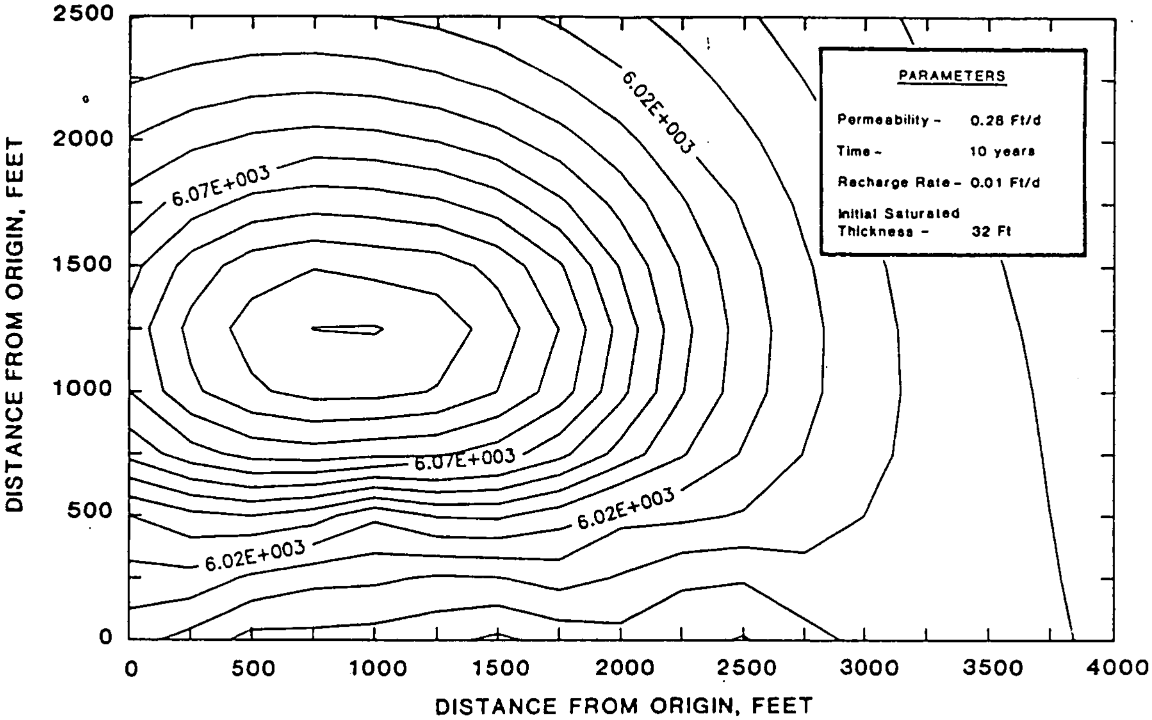
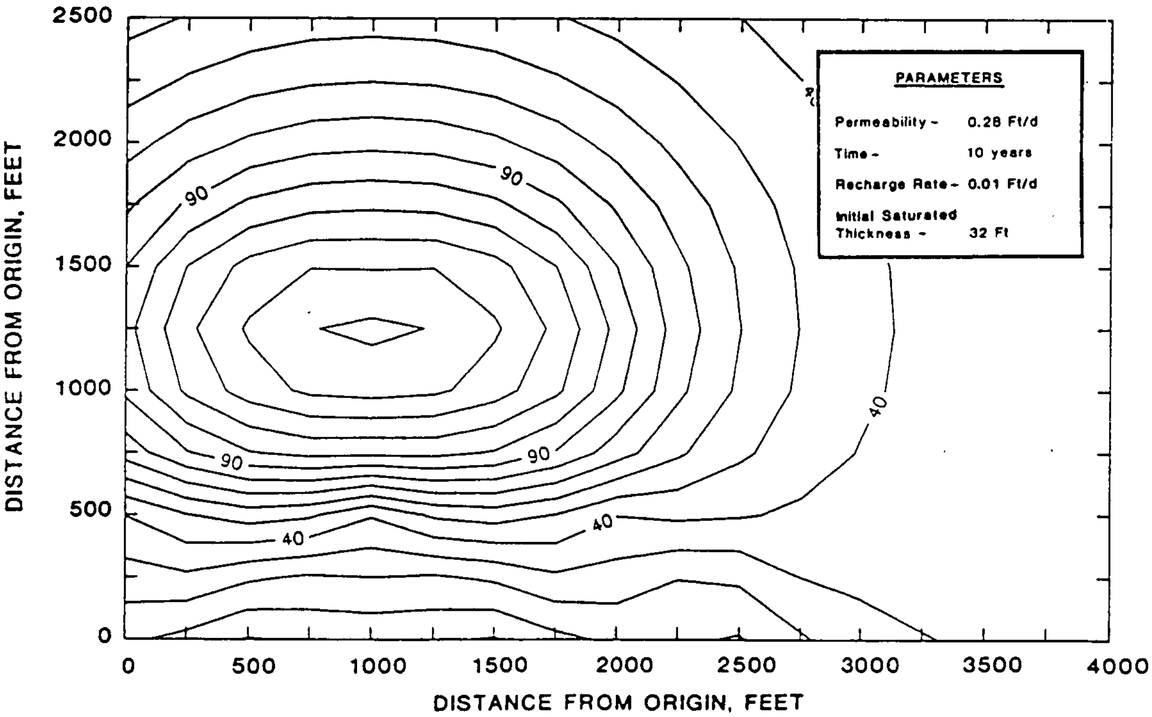
AREA 1 -- CASE 1

FIGURE
B-1



a.) Calculated water-table elevation at 10 years.



b.) Calculated saturated thickness at 10 years

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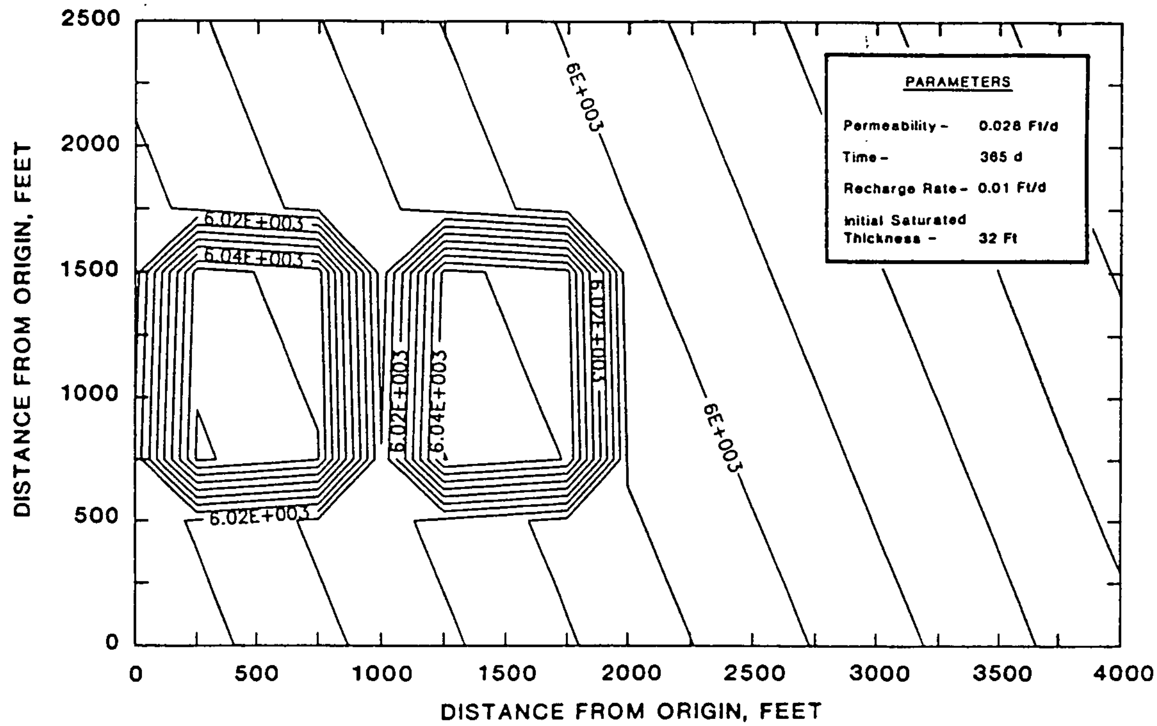
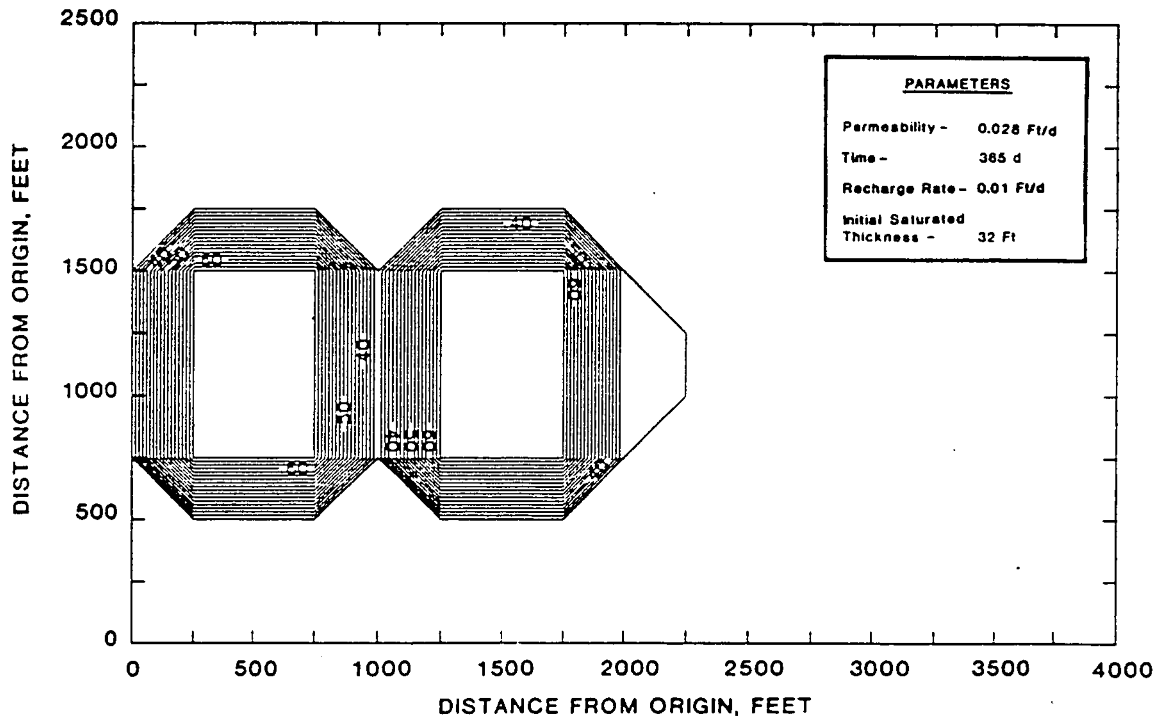
AREA 1 — CASE 2

FIGURE
B-2



a.) Calculated water-table elevation at 365 days.

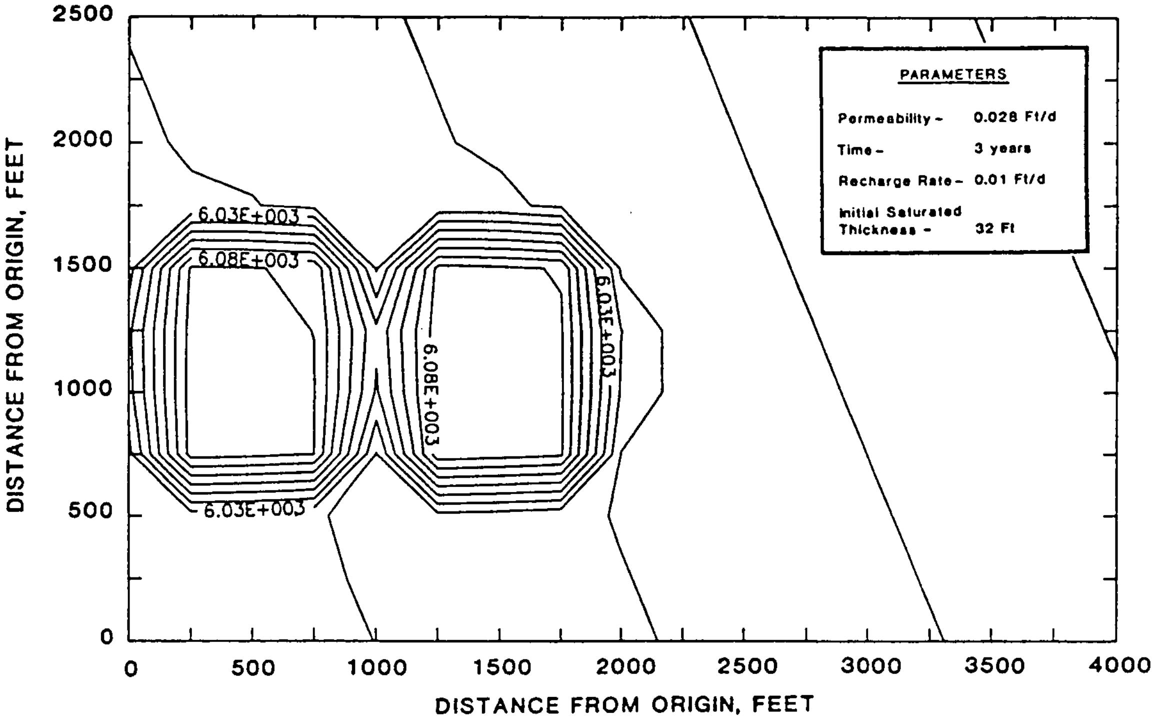


b.) Calculated saturated thickness at 365 days

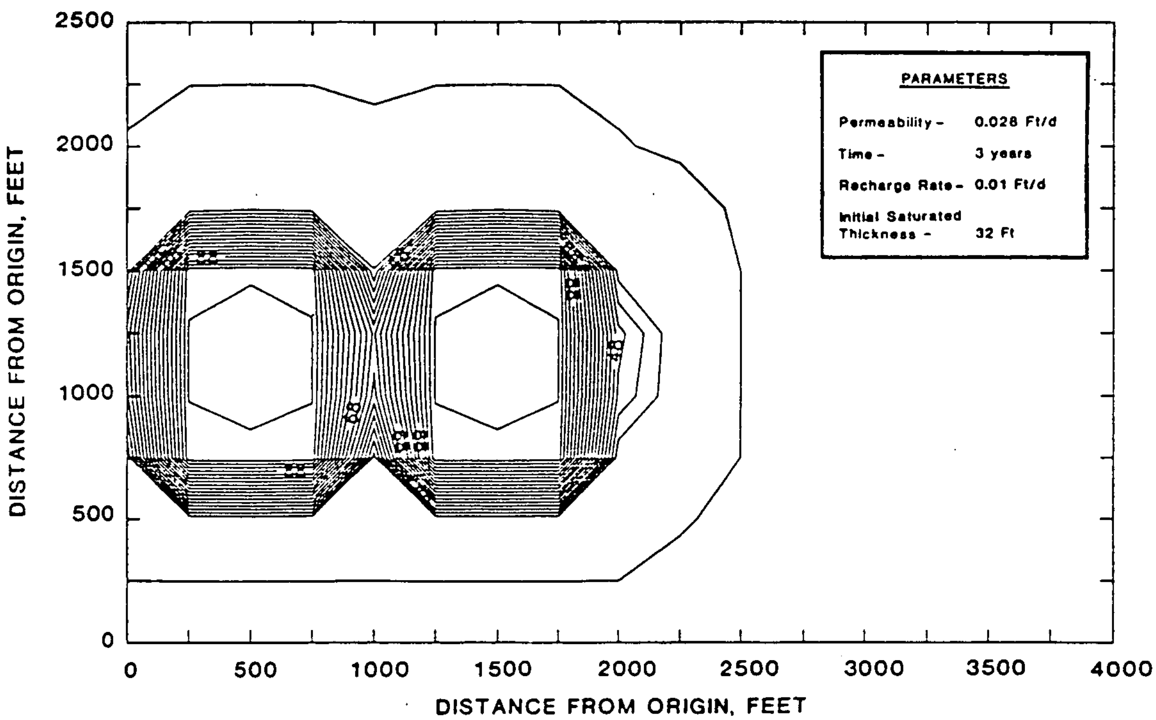
S. S. PAPADOPULOS & ASSOCIATES, INC.
CONSULTING GROUND WATER HYDROLOGISTS

AREA 1 — CASE 3

FIGURE B-3



a.) Calculated water-table elevation at 3 years

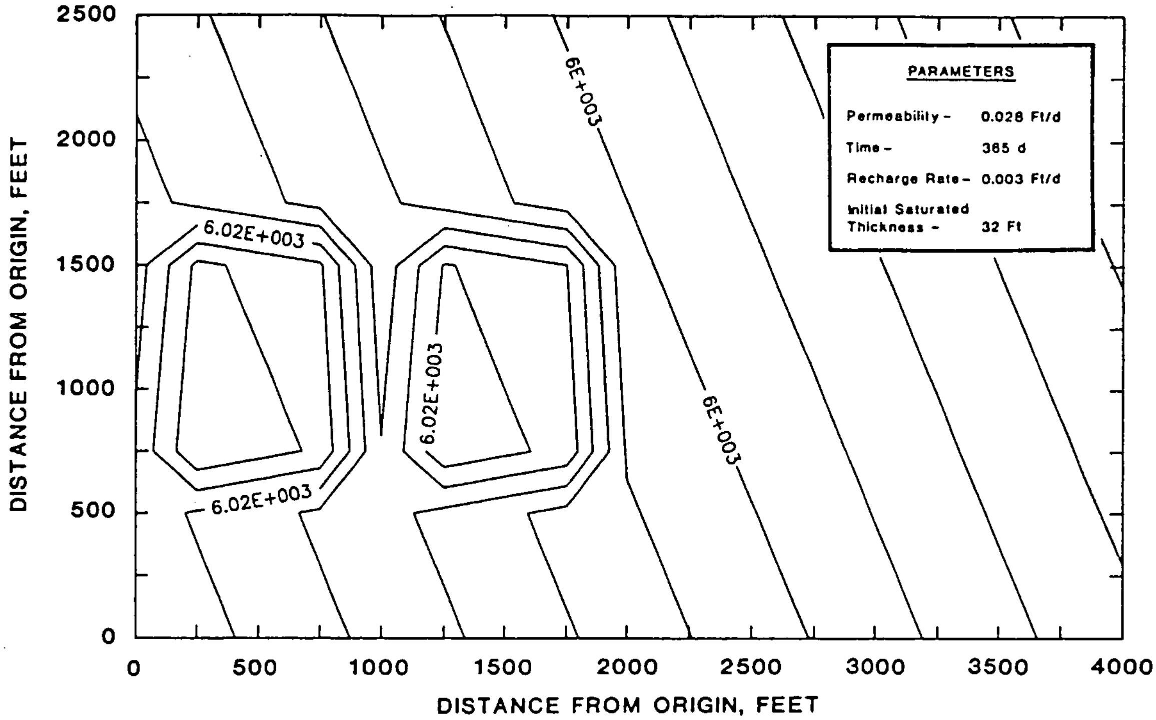


b.) Calculated saturated thickness at 3 years

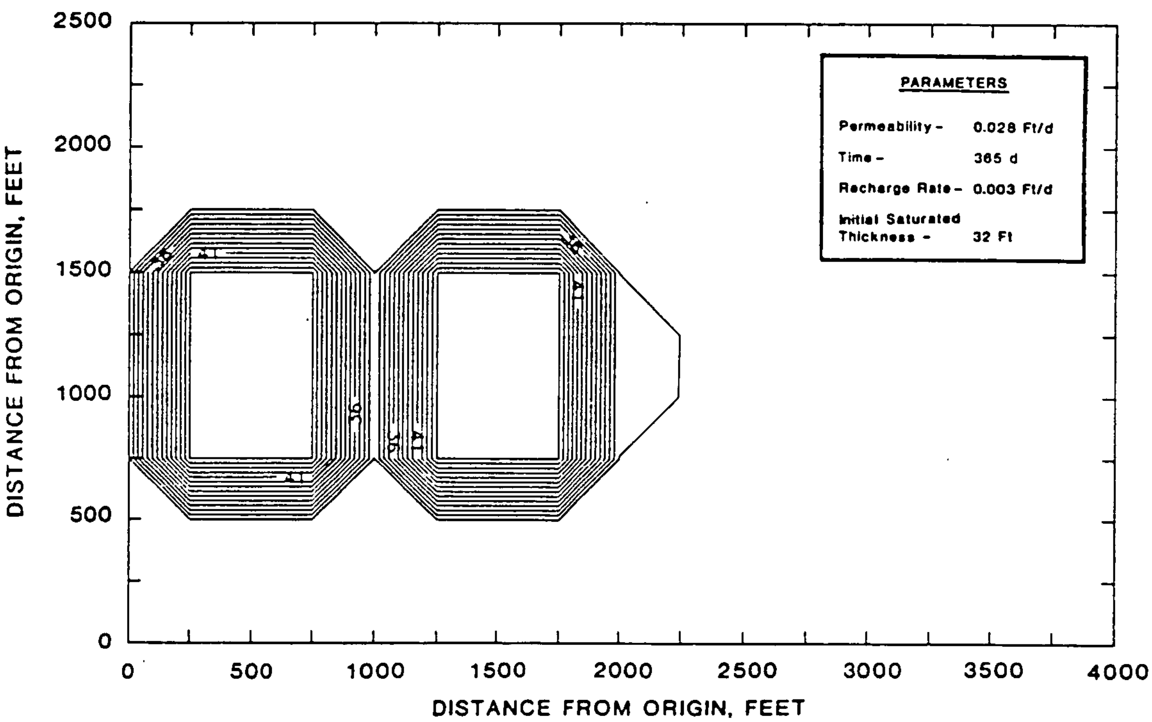
S. S. PAPADOPULOS & ASSOCIATES, INC.
CONSULTING GROUND WATER HYDROLOGISTS

AREA 1 -- CASE 4

FIGURE
B-4



a.) Calculated water-table elevation at 365 days.

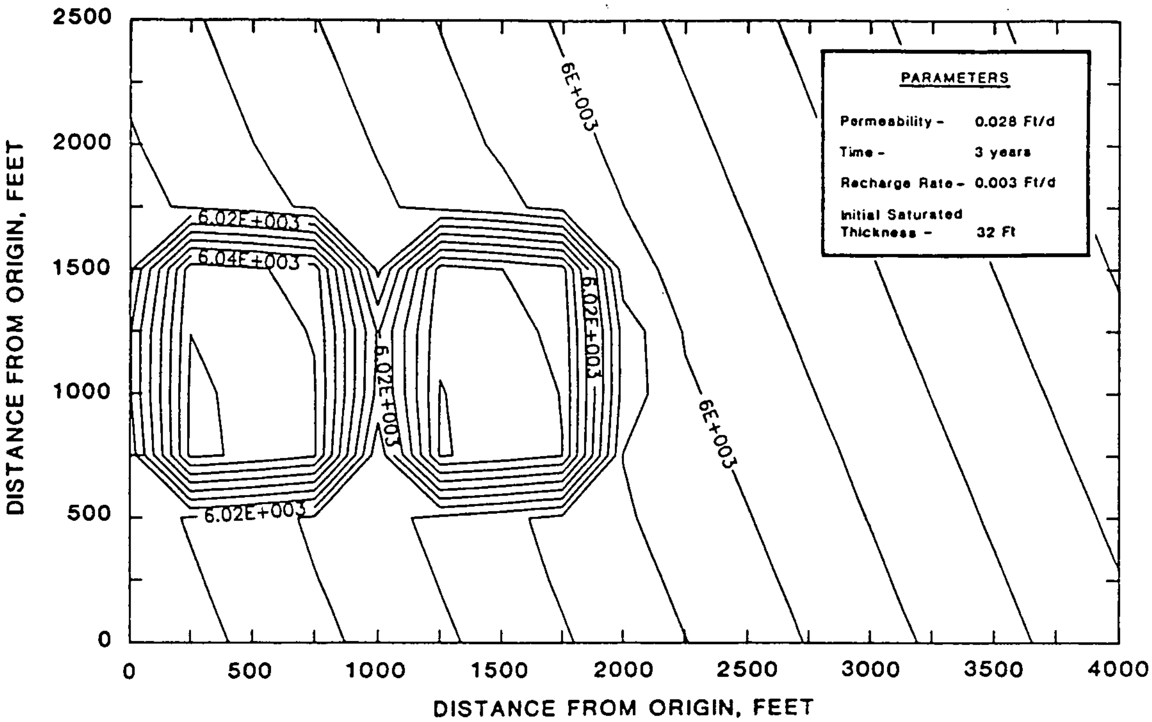


b.) Calculated saturated thickness at 365 days

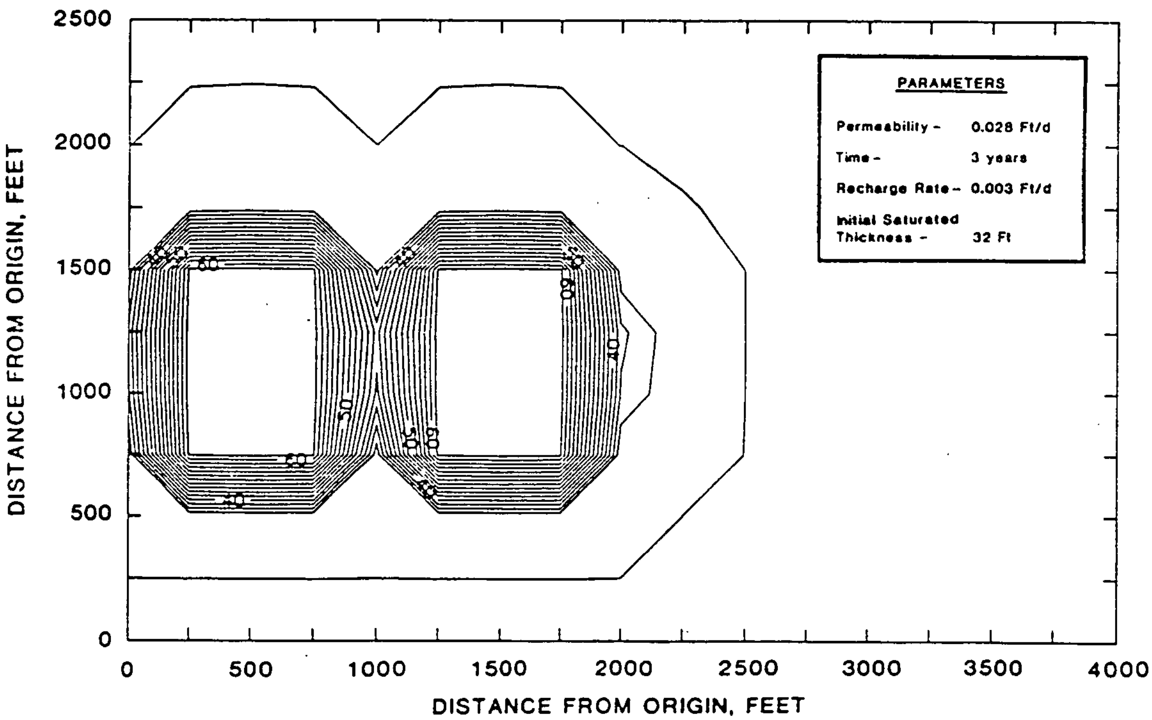
S. S. PAPADOPULOS & ASSOCIATES, INC.
CONSULTING GROUND WATER HYDROLOGISTS

AREA 1 -- CASE 5

FIGURE B-5



a.) Calculated water-table elevation at 3 years

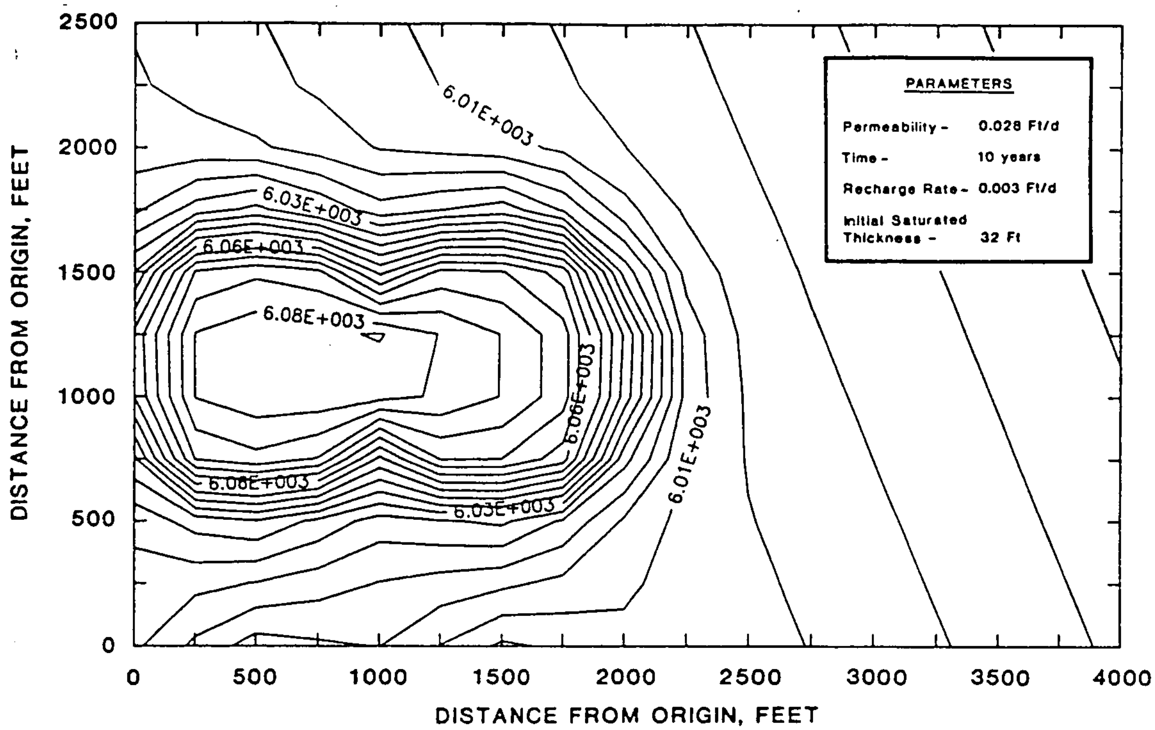


b.) Calculated saturated thickness at 3 years

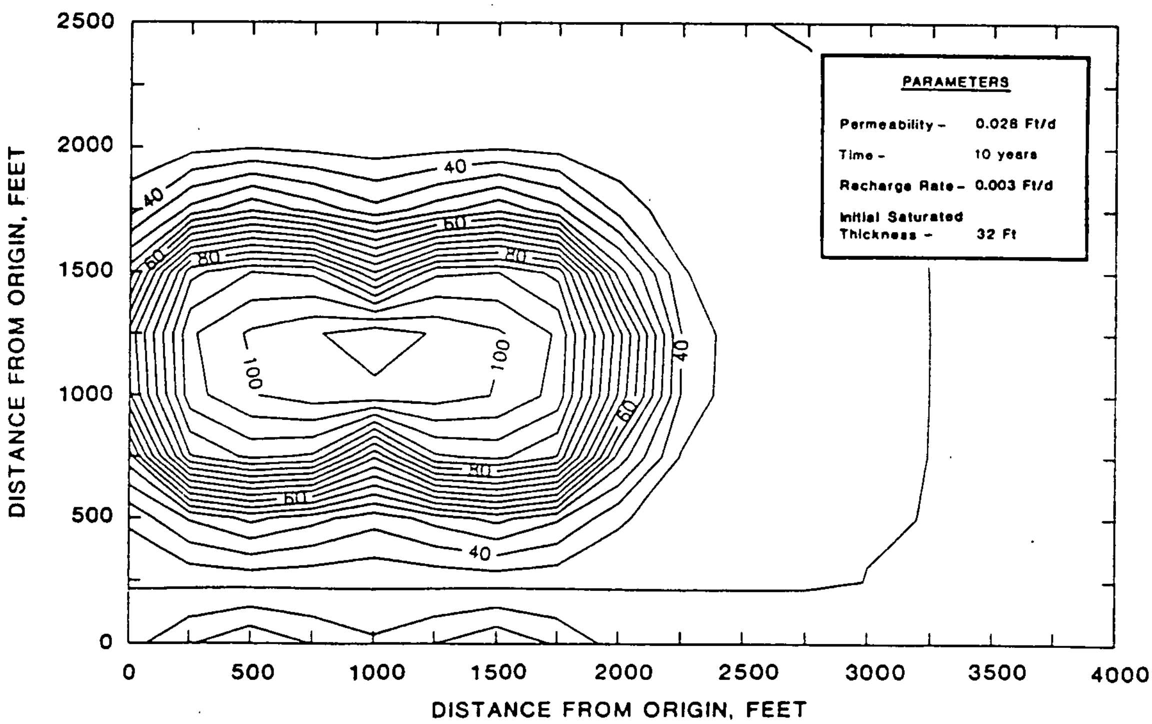
S. S. PAPADOPULOS & ASSOCIATES, INC.
CONSULTING GROUND WATER HYDROLOGISTS

AREA 1 -- CASE 6

FIGURE B-6

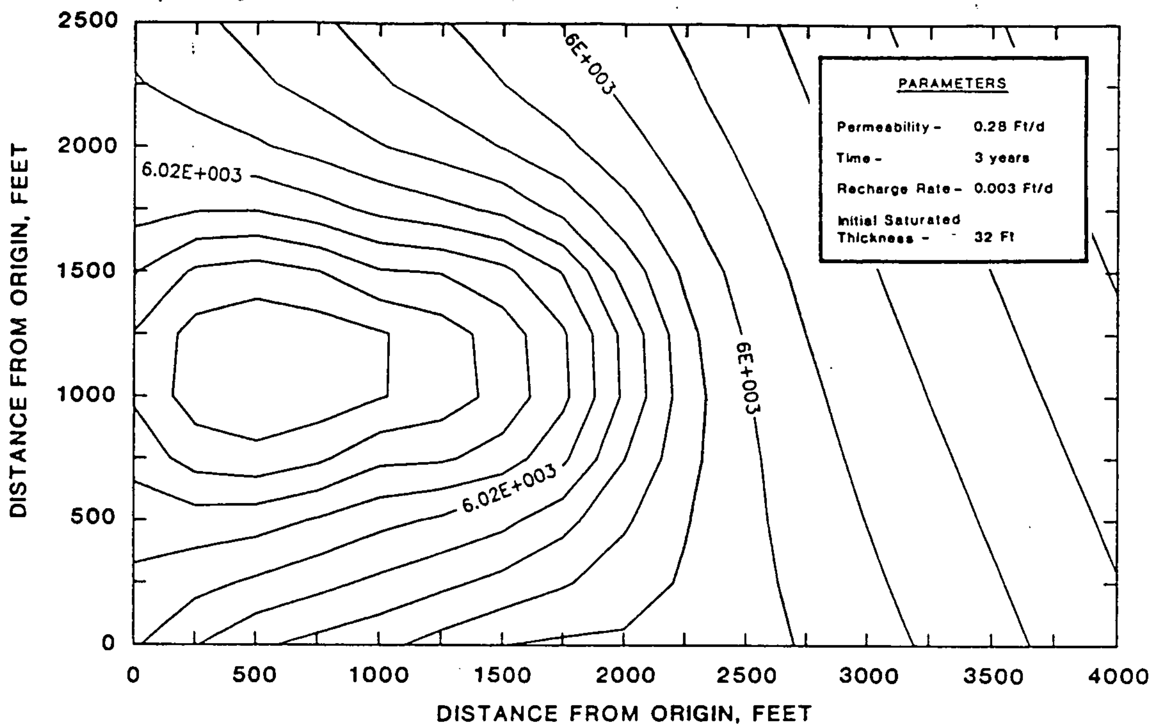


a.) Calculated water-table elevation at 10 years

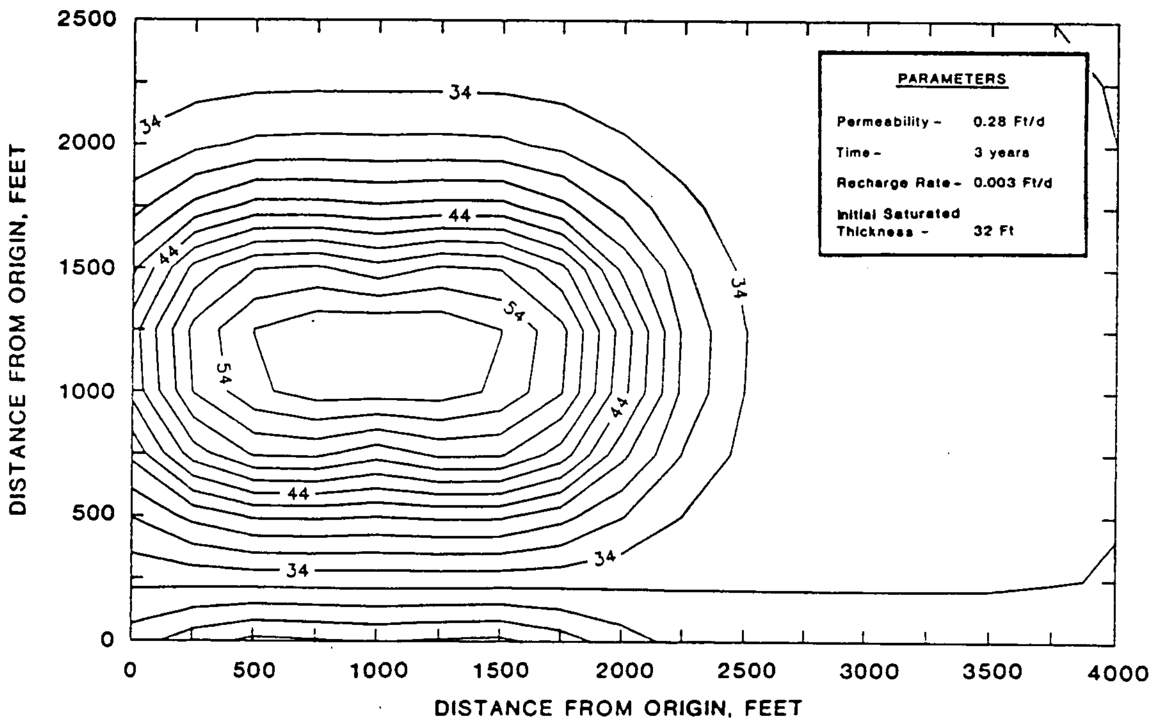


b.) Calculated saturated thickness at 10 years

S. S. PAPADOPULOS & ASSOCIATES, INC. CONSULTING GROUND WATER HYDROLOGISTS	AREA 1 -- CASE 7	FIGURE B-7

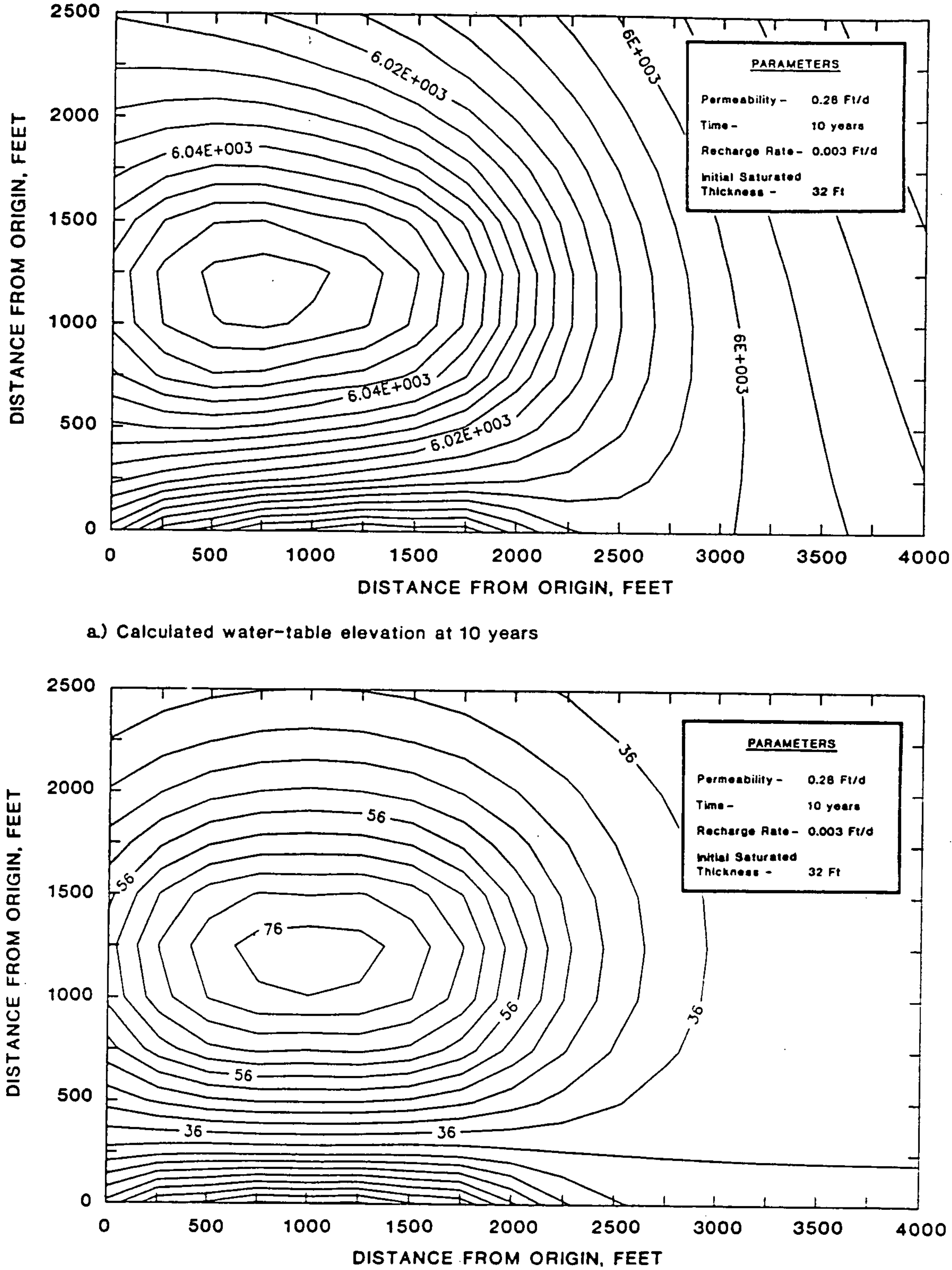


a.) Calculated water-table elevation at 3 years



b.) Calculated saturated thickness at 3 years

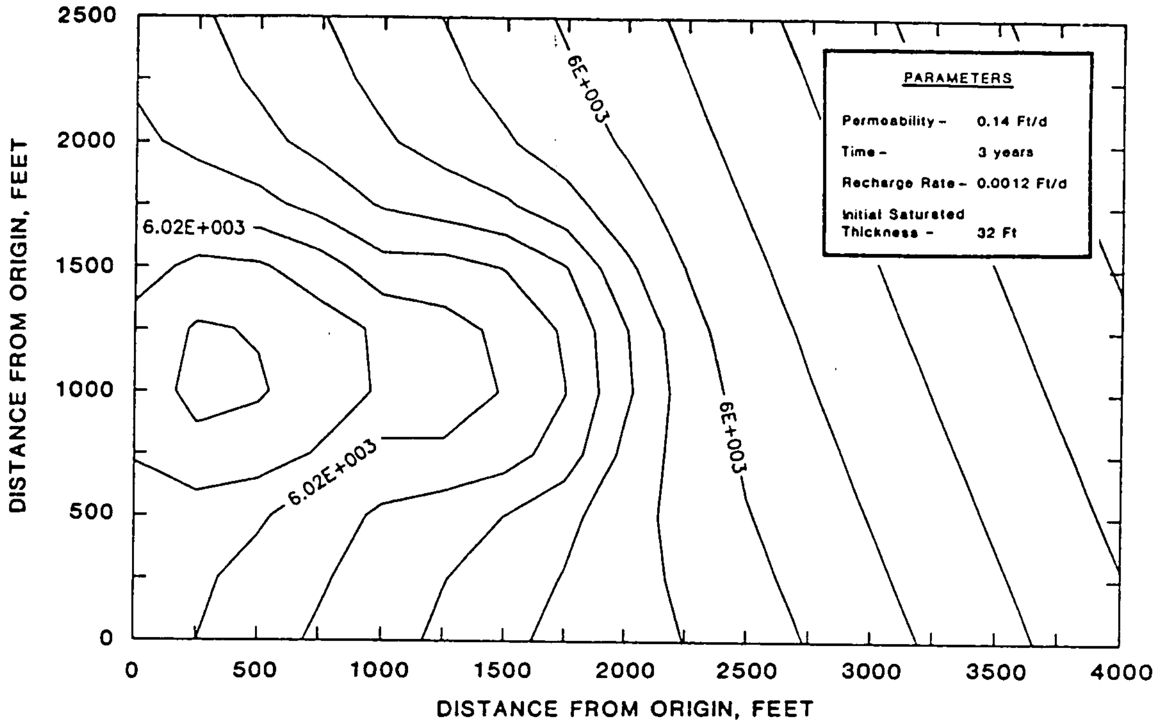
S. S. PAPADOPULOS & ASSOCIATES, INC. CONSULTING GROUND WATER HYDROLOGISTS	AREA 1 — CASE 8	FIGURE B-8



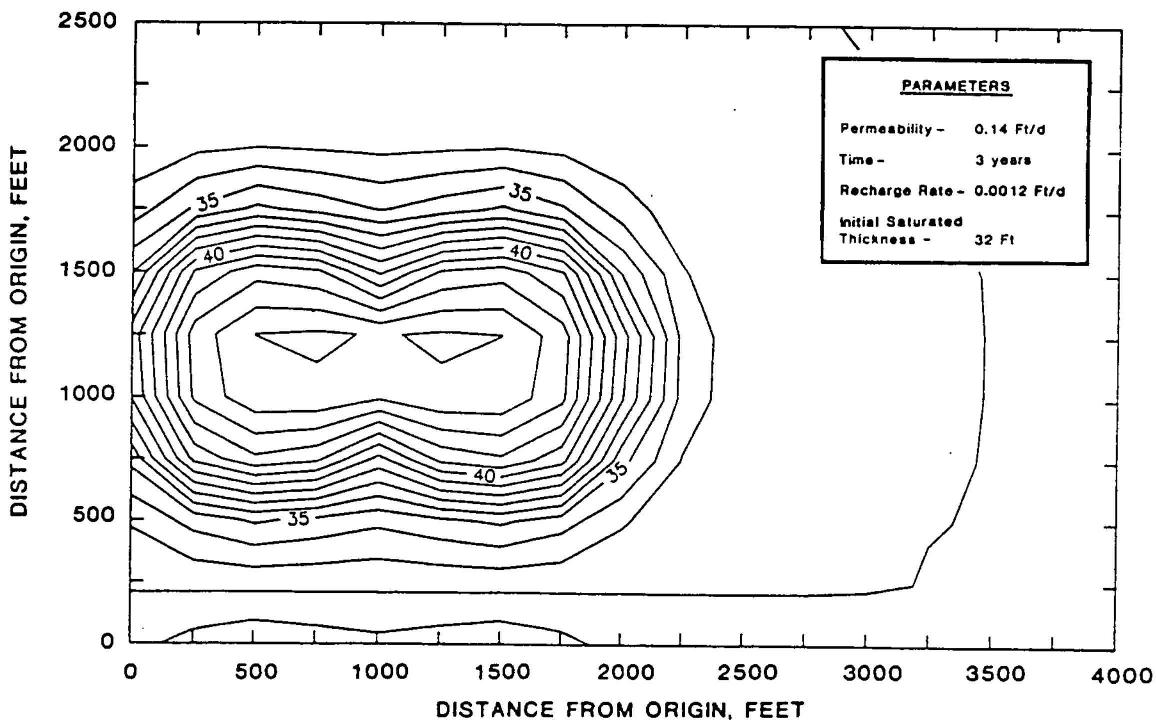
a.) Calculated water-table elevation at 10 years

b.) Calculated saturated thickness at 10 years

S. S. PAPADOPULOS & ASSOCIATES, INC. CONSULTING GROUND WATER HYDROLOGISTS	AREA 1 -- CASE 9	FIGURE B-9



a.) Calculated water-table elevation at 3 years

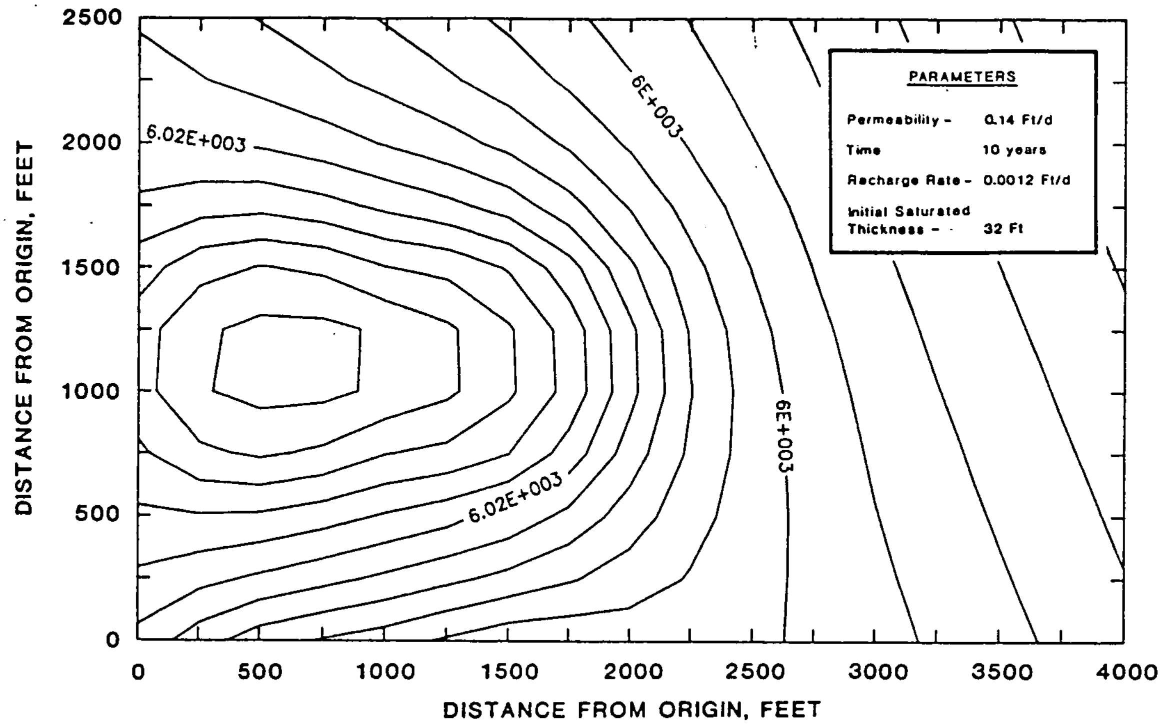


b.) Calculated saturated thickness at 3 years

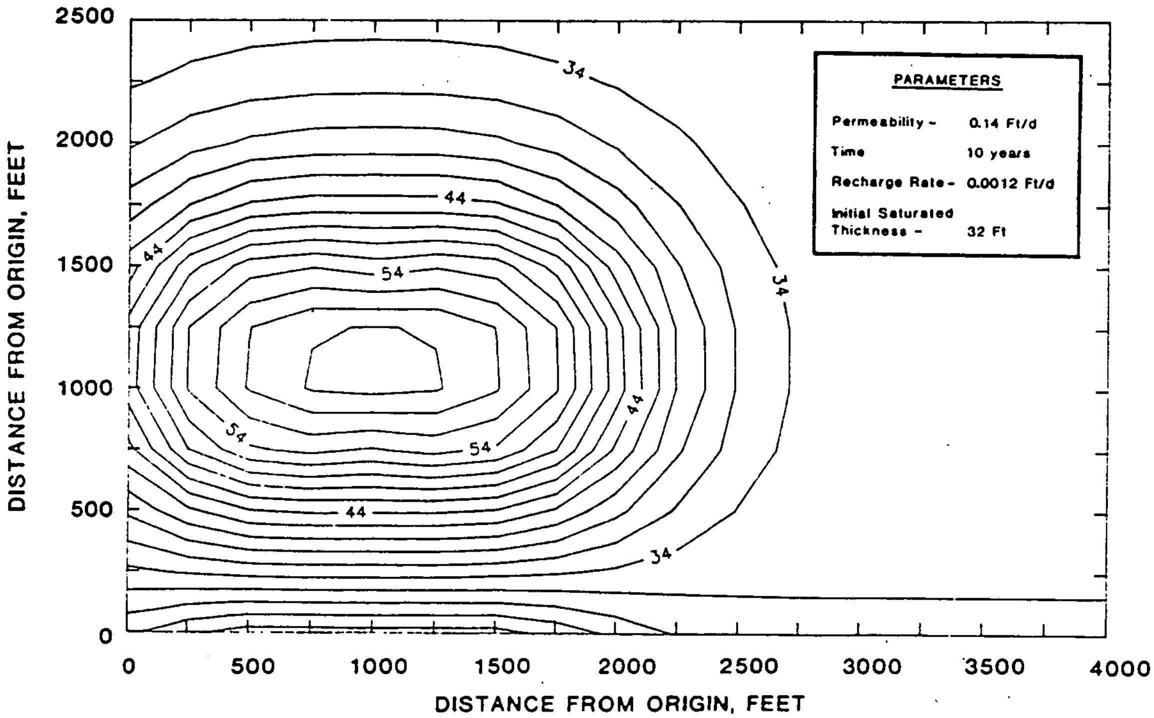
S. S. PAPADOPULOS & ASSOCIATES, INC.
CONSULTING GROUND WATER HYDROLOGISTS

AREA 1 -- CASE 10

FIGURE B-10



a.) Calculated water-table elevation at 10 years

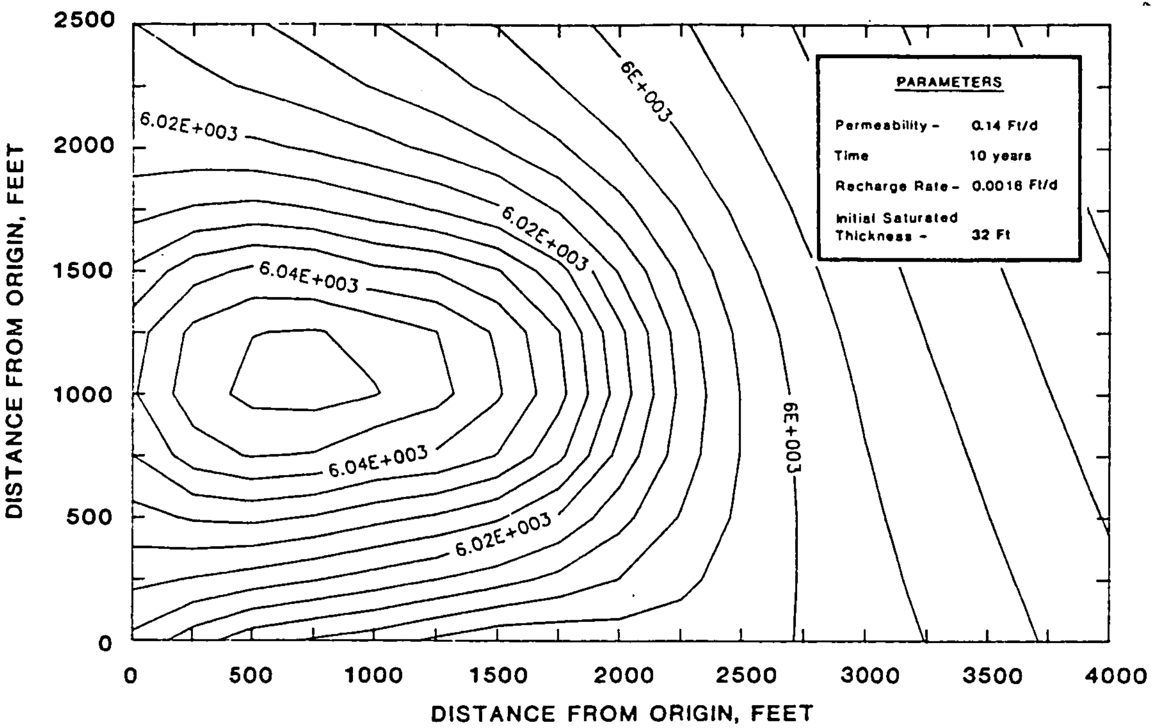


b.) Calculated saturated thickness at 10 years

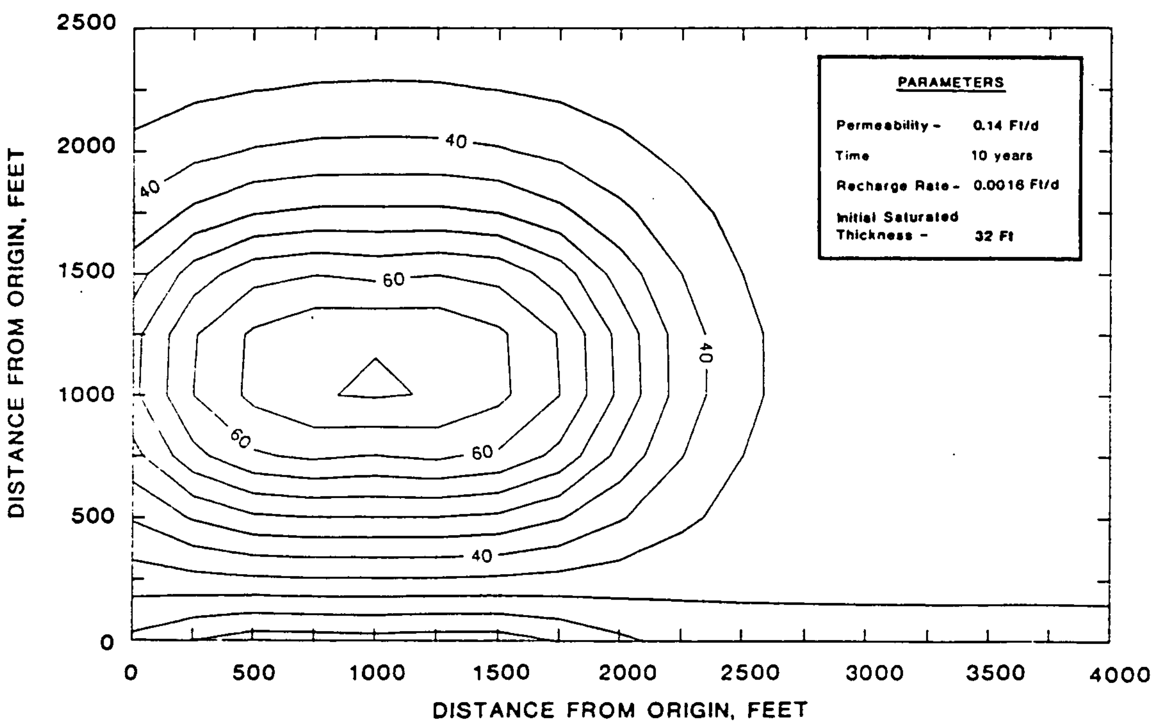
S. S. PAPADOPULOS & ASSOCIATES, INC.
CONSULTING GROUND WATER HYDROLOGISTS

AREA 1 -- CASE 11

FIGURE B-11

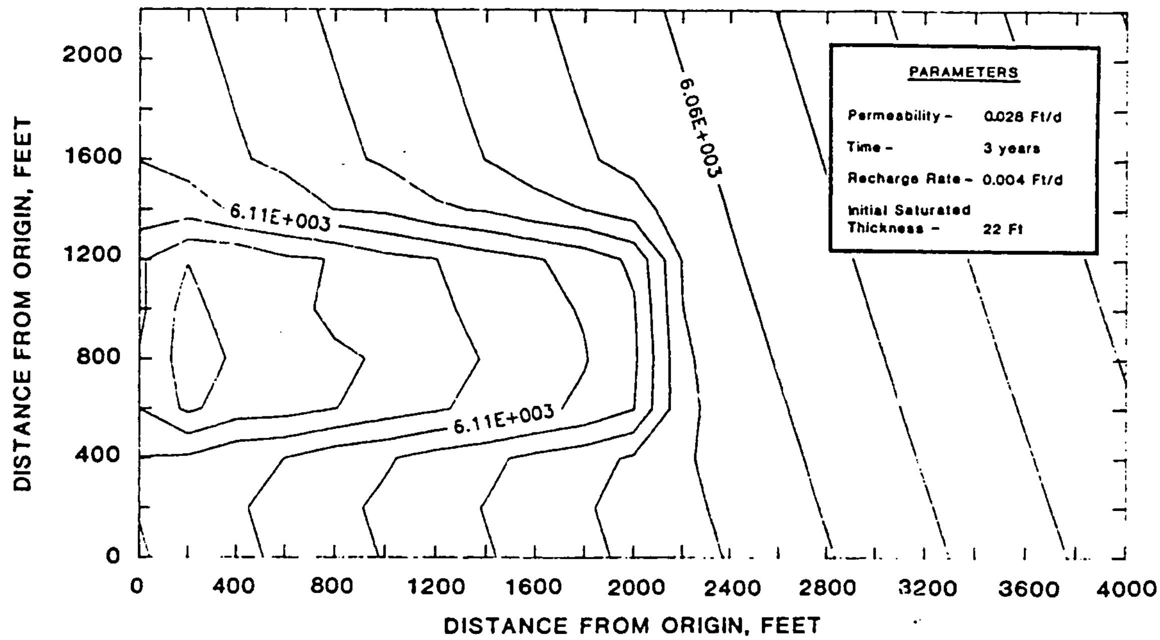


a.) Calculated water-table elevation at 10 years

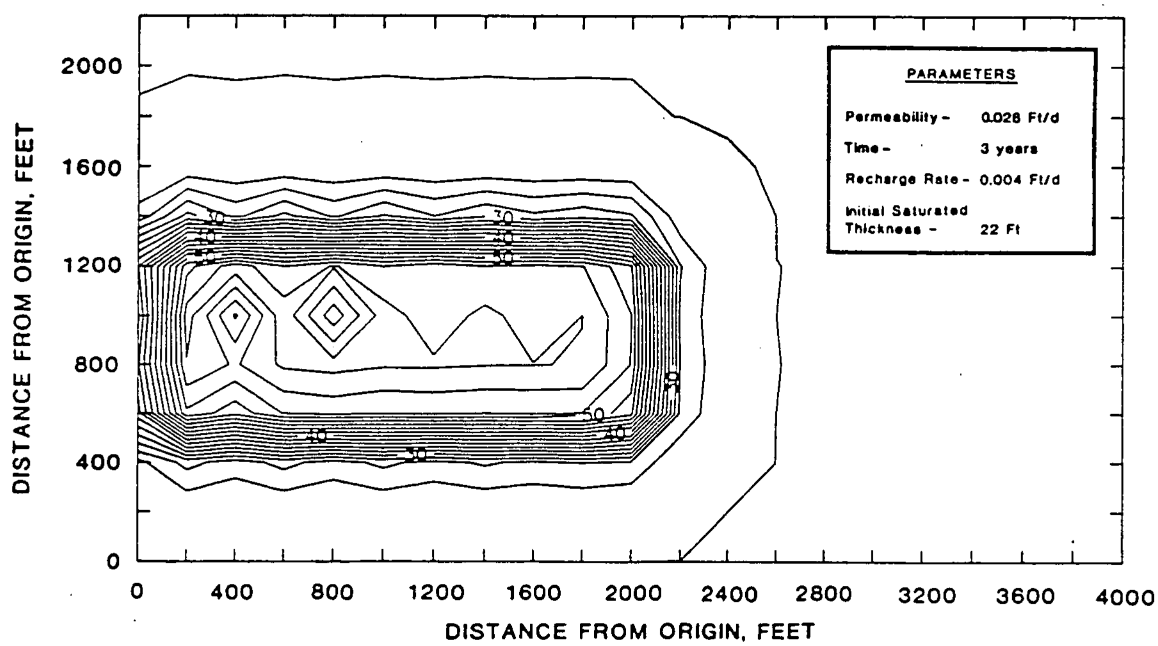


b.) Calculated saturated thickness at 10 years

S. S. PAPADOPULOS & ASSOCIATES, INC. CONSULTING GROUND WATER HYDROLOGISTS	AREA 1 -- CASE 12	FIGURE B-12



a.) Calculated water-table elevation at 3 years

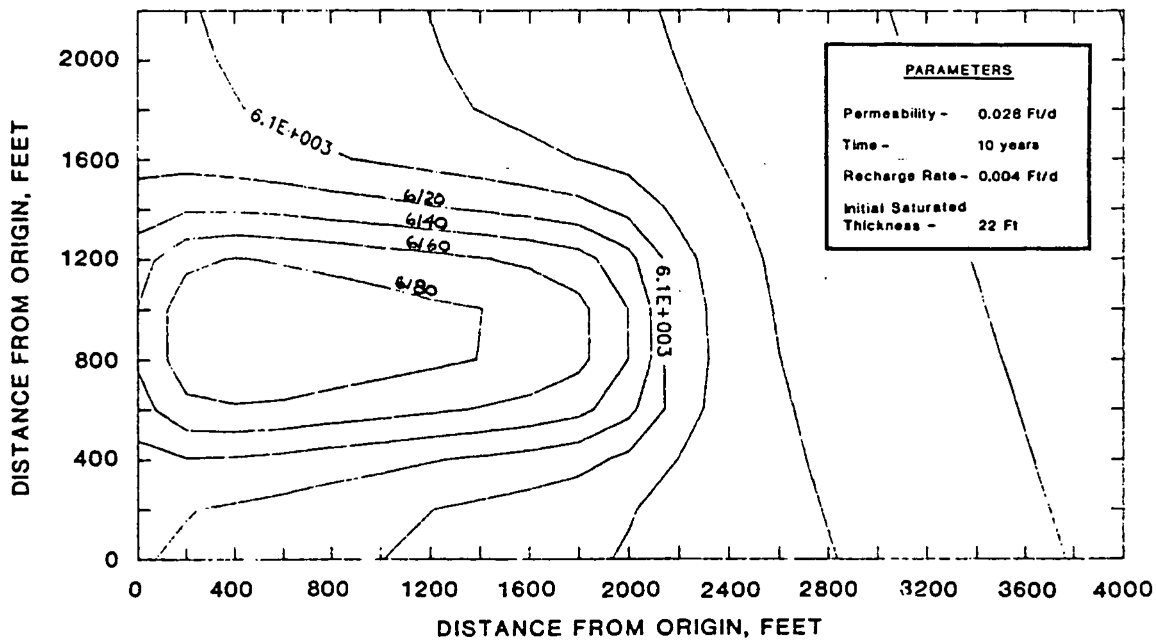


b.) Calculated saturated thickness at 3 years

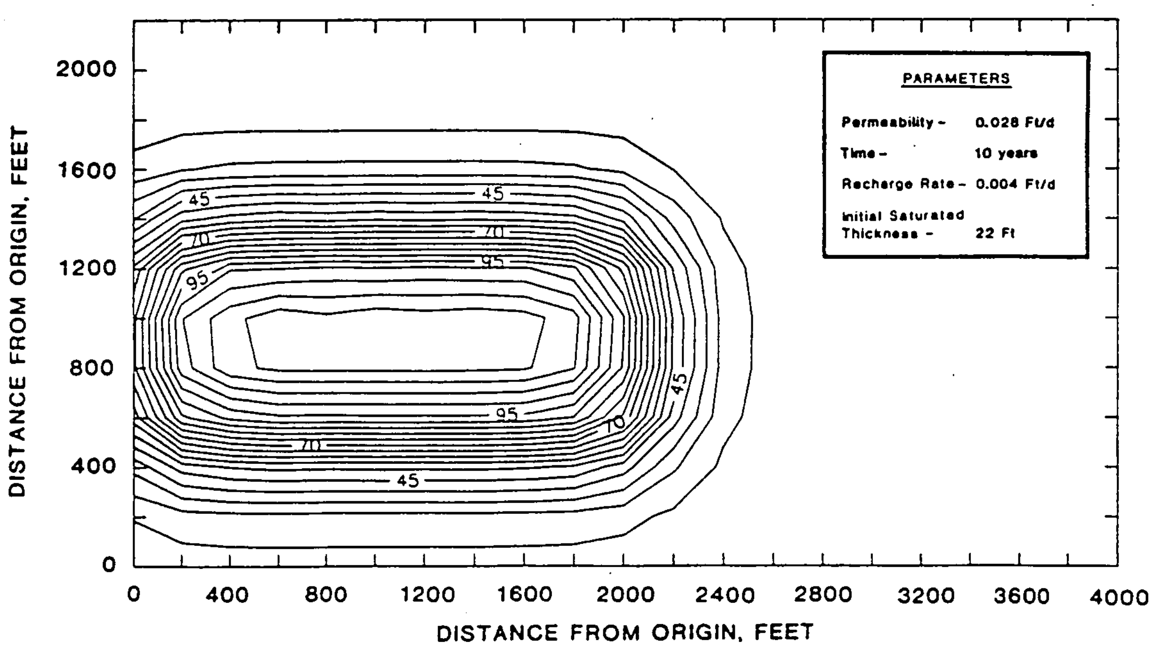
S. S. PAPADOPULOS & ASSOCIATES, INC.
CONSULTING GROUND WATER HYDROLOGISTS

AREA 2 -- CASE 1

FIGURE B-13



a.) Calculated water-table elevation at 10 years

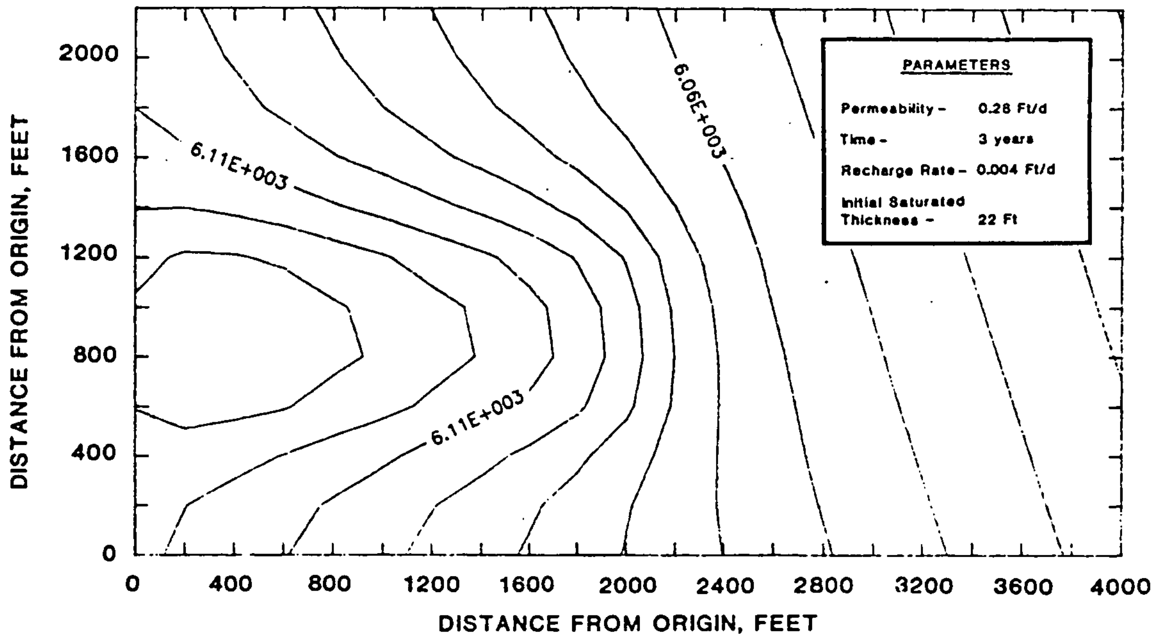


b.) Calculated saturated thickness at 10 years

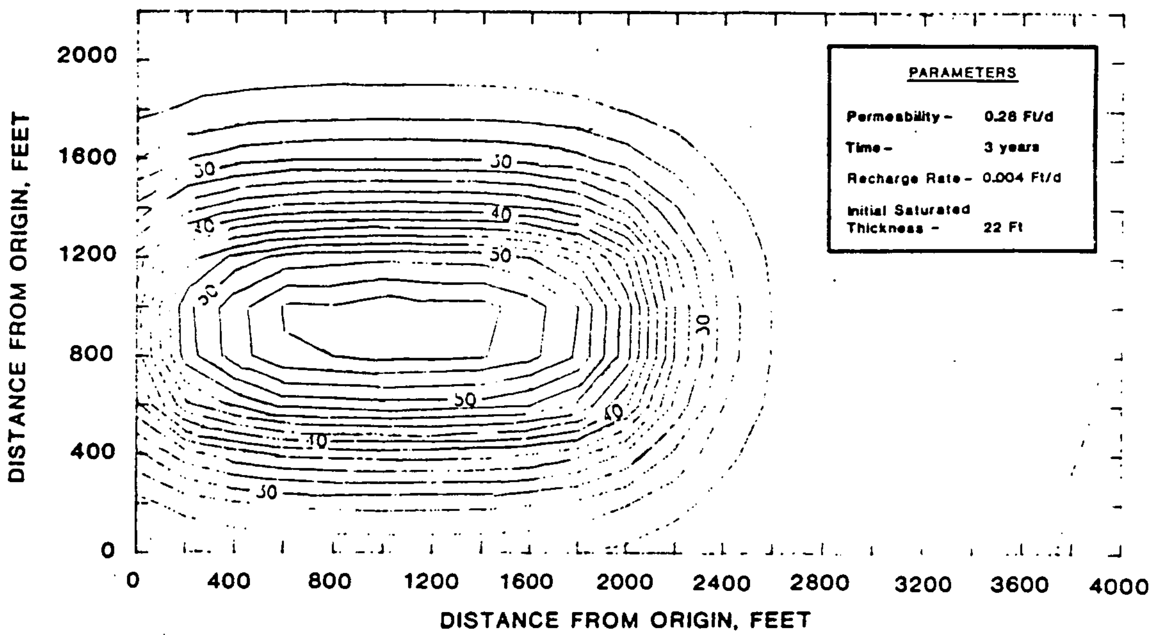
S. S. PAPADOPULOS & ASSOCIATES, INC.
CONSULTING GROUND WATER HYDROLOGISTS

AREA 2 — CASE 2

FIGURE B-14



a.) Calculated water-table elevation at 3 years

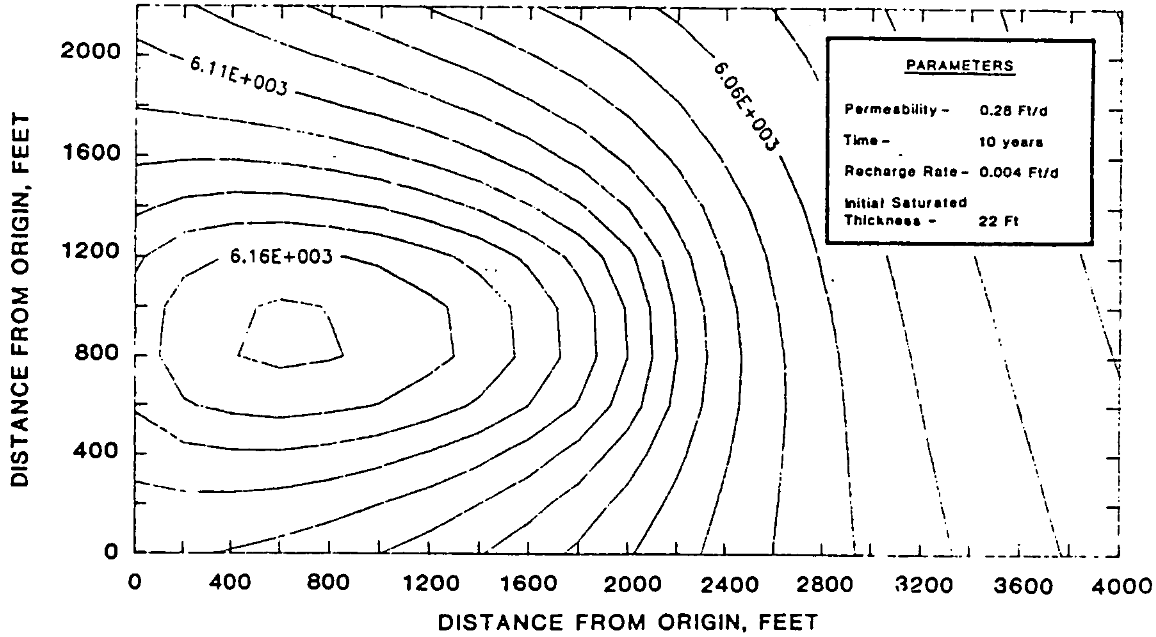


b.) Calculated saturated thickness at 3 years

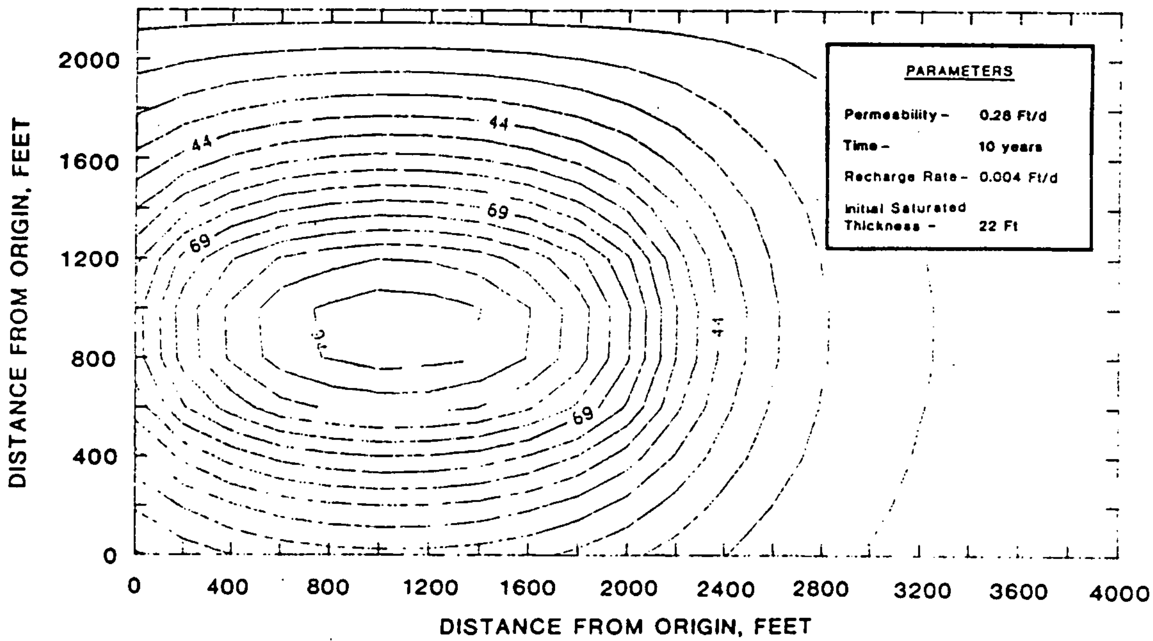
S. S. PAPADOPULOS & ASSOCIATES, INC.
CONSULTING GROUND WATER HYDROLOGISTS

AREA 2 — CASE 3

FIGURE B-15



a.) Calculated water-table elevation at 10 years

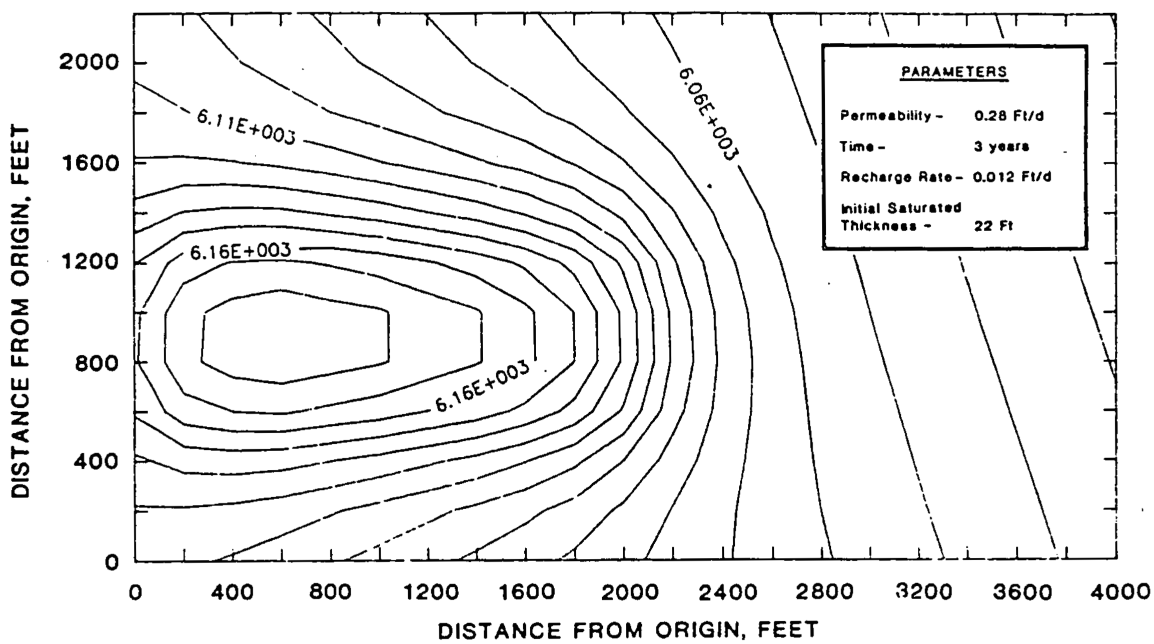


b.) Calculated saturated thickness at 10 years

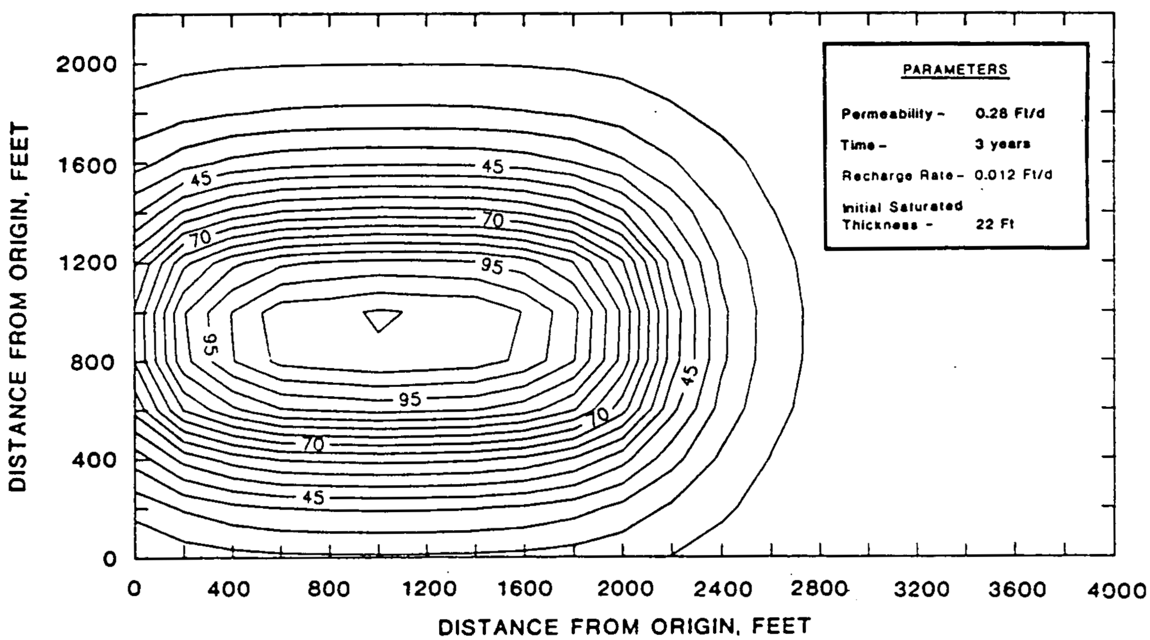
S. S. PAPADOPULOS & ASSOCIATES, INC.
CONSULTING GROUND WATER HYDROLOGISTS

AREA 2 -- CASE 4

FIGURE
B-16

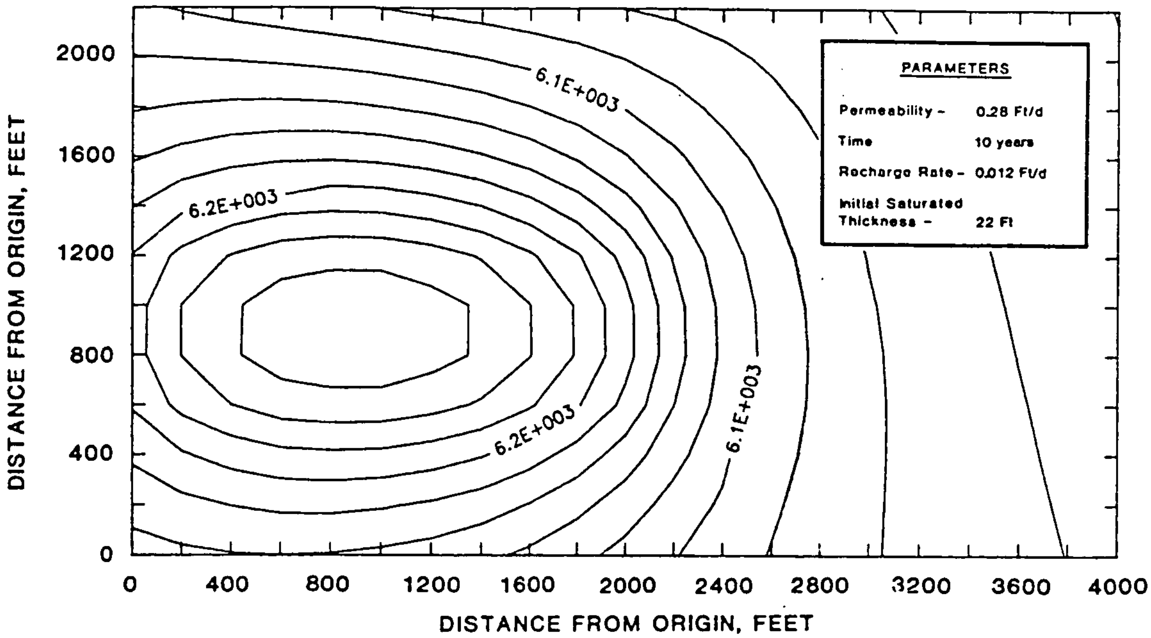


a.) Calculated water-table elevation at 3 years

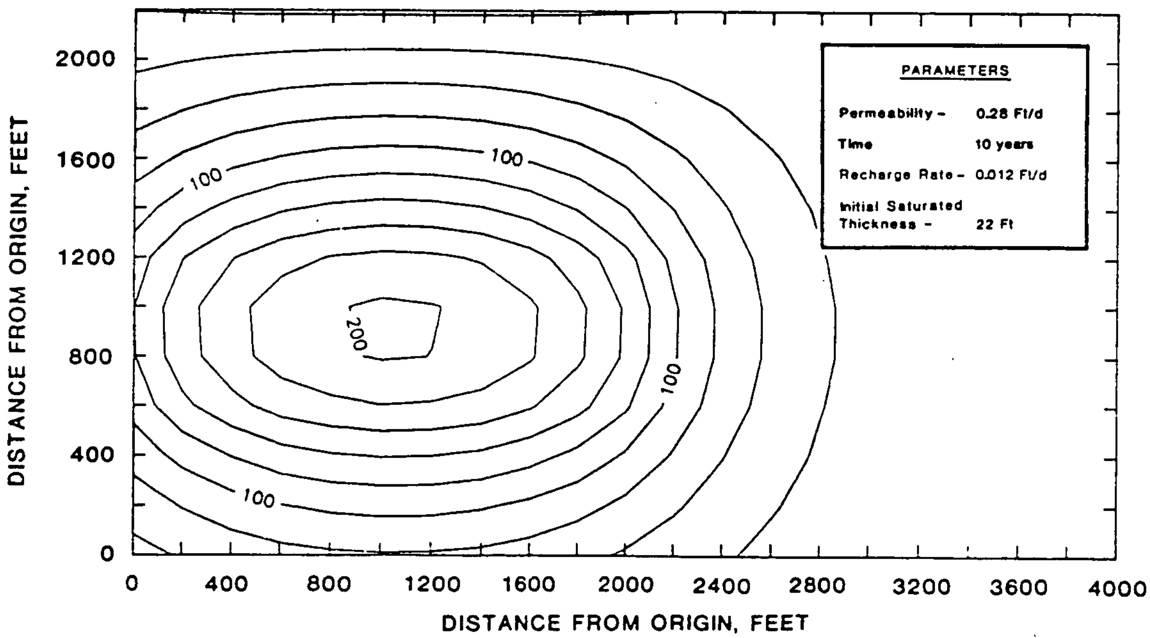


b.) Calculated saturated thickness at 3 years

S. S. PAPADOPULOS & ASSOCIATES, INC. CONSULTING GROUND WATER HYDROLOGISTS	AREA 2 -- CASE 5	FIGURE B-17



a.) Calculated water-table elevation at 10 years

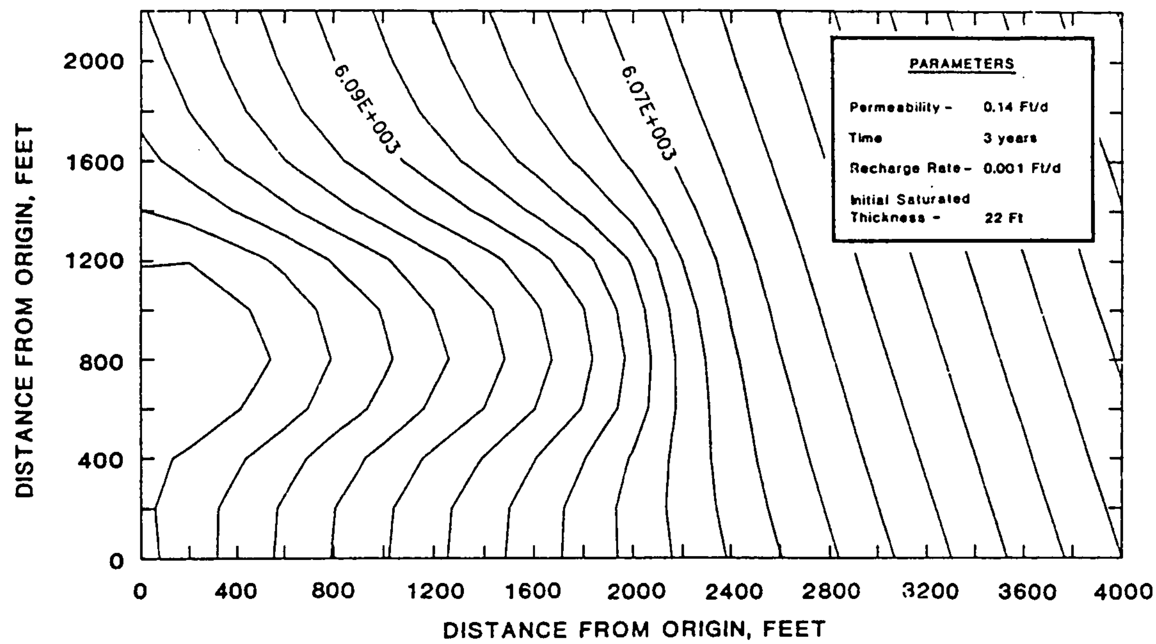


b.) Calculated saturated thickness at 10 years

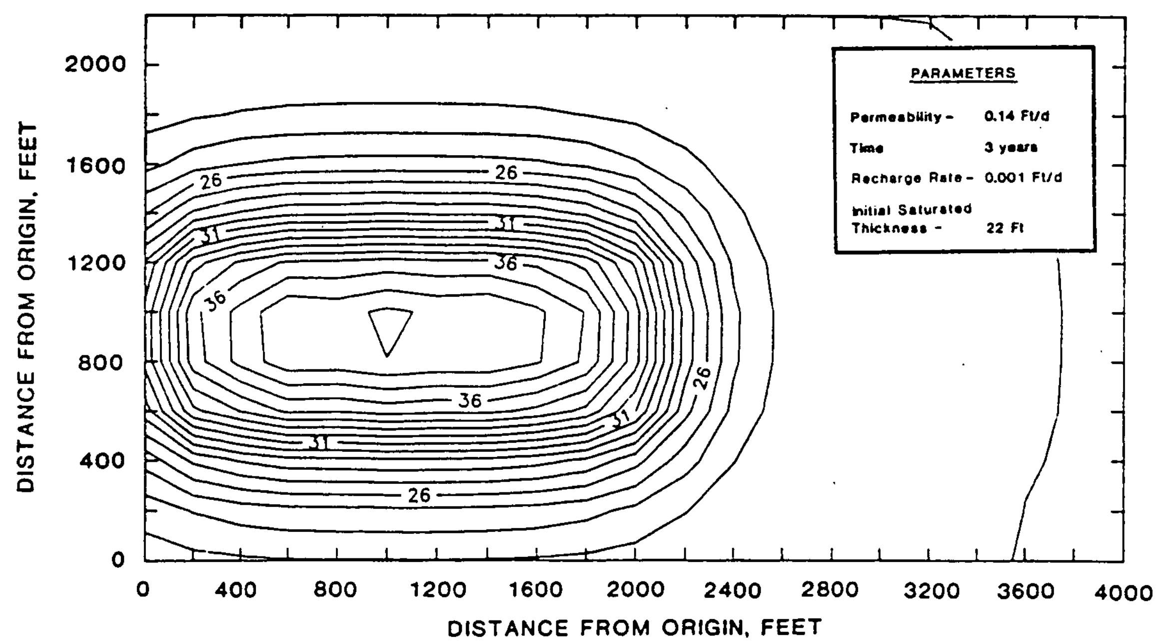
S. S. PAPADOPULOS & ASSOCIATES, INC.
CONSULTING GROUND WATER HYDROLOGISTS

AREA 2 -- CASE 6

FIGURE B-18

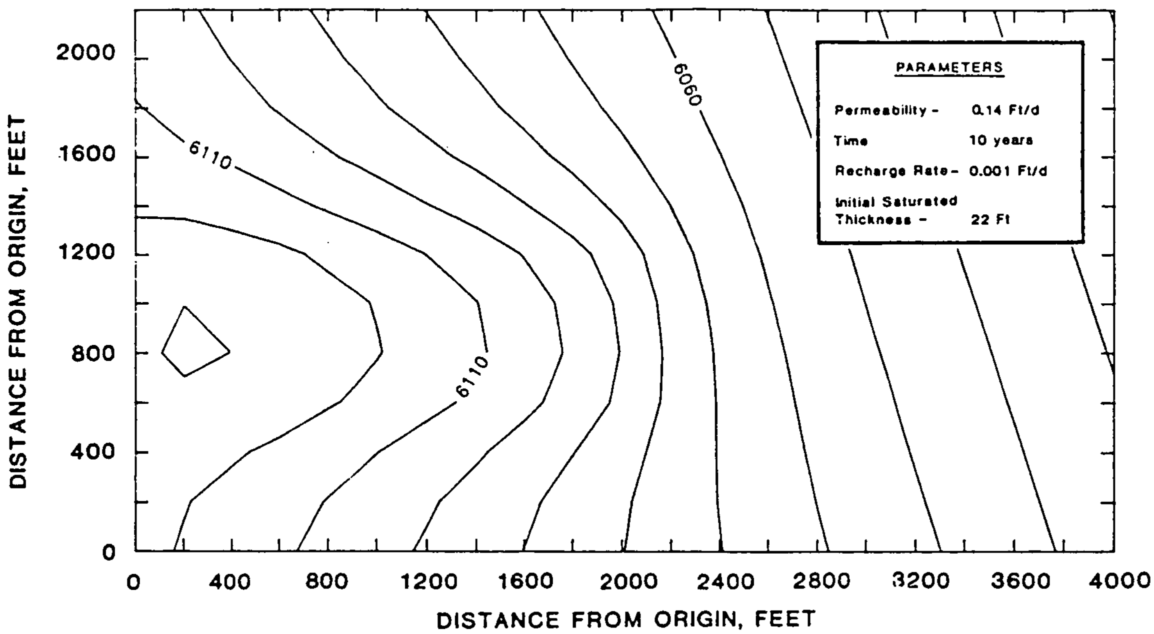


a.) Calculated water-table elevation at 3 years

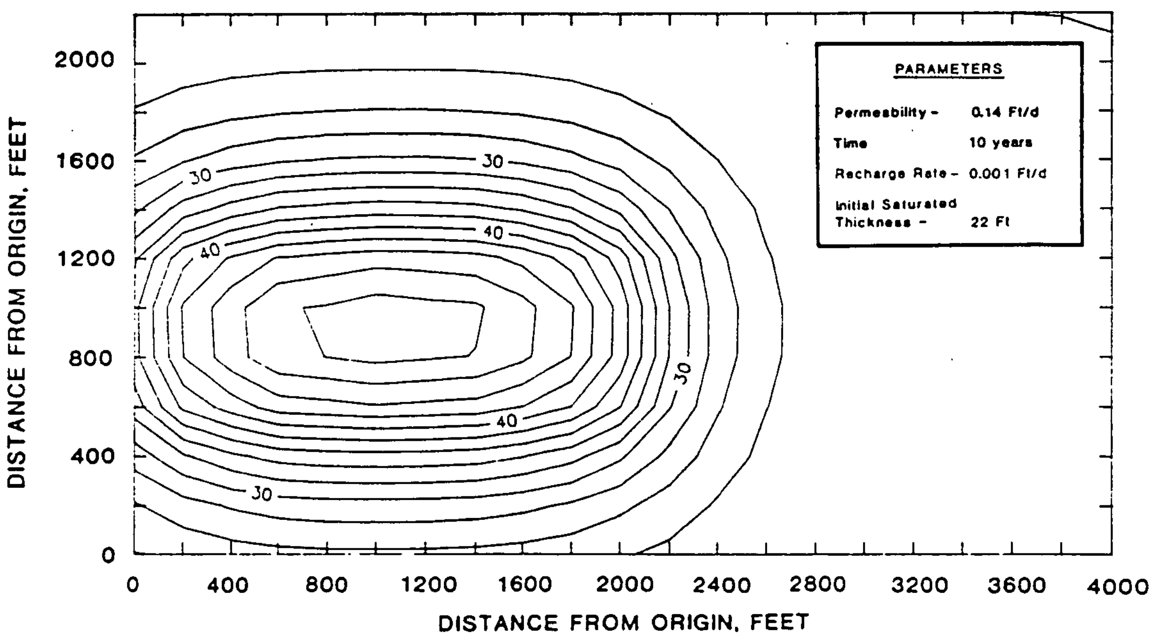


b.) Calculated saturated thickness at 3 years

S. S. PAPADOPULOS & ASSOCIATES, INC. CONSULTING GROUND WATER HYDROLOGISTS	AREA 2 — CASE 7	FIGURE B-19



a.) Calculated water-table elevation at 10 years

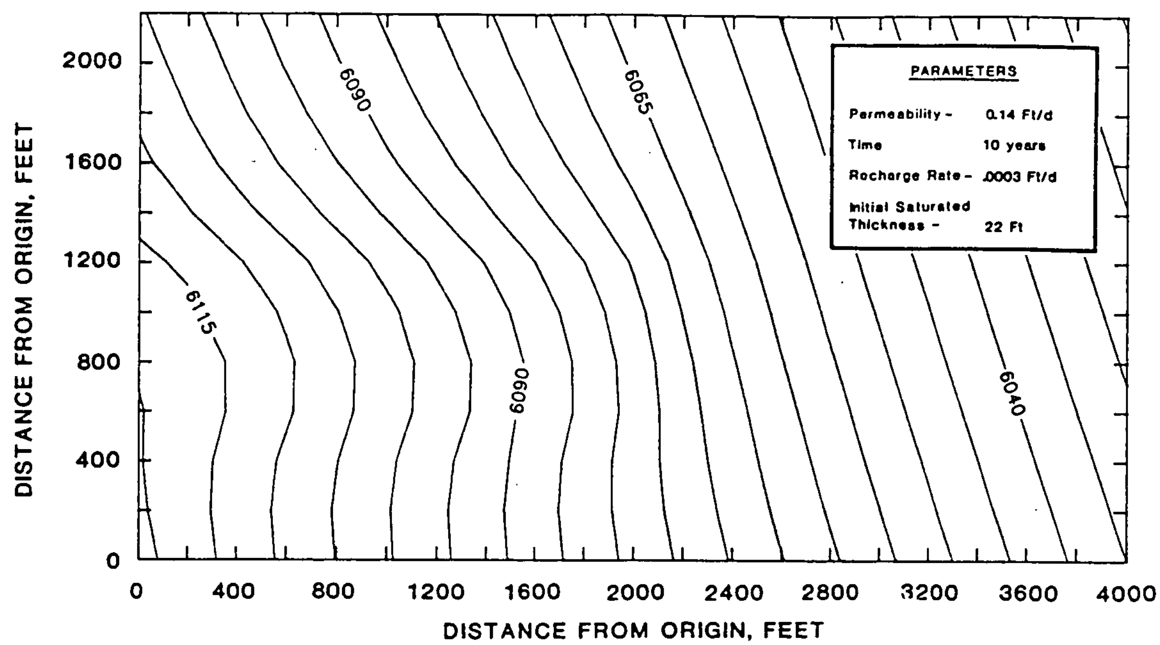


b.) Calculated saturated thickness at 10 years

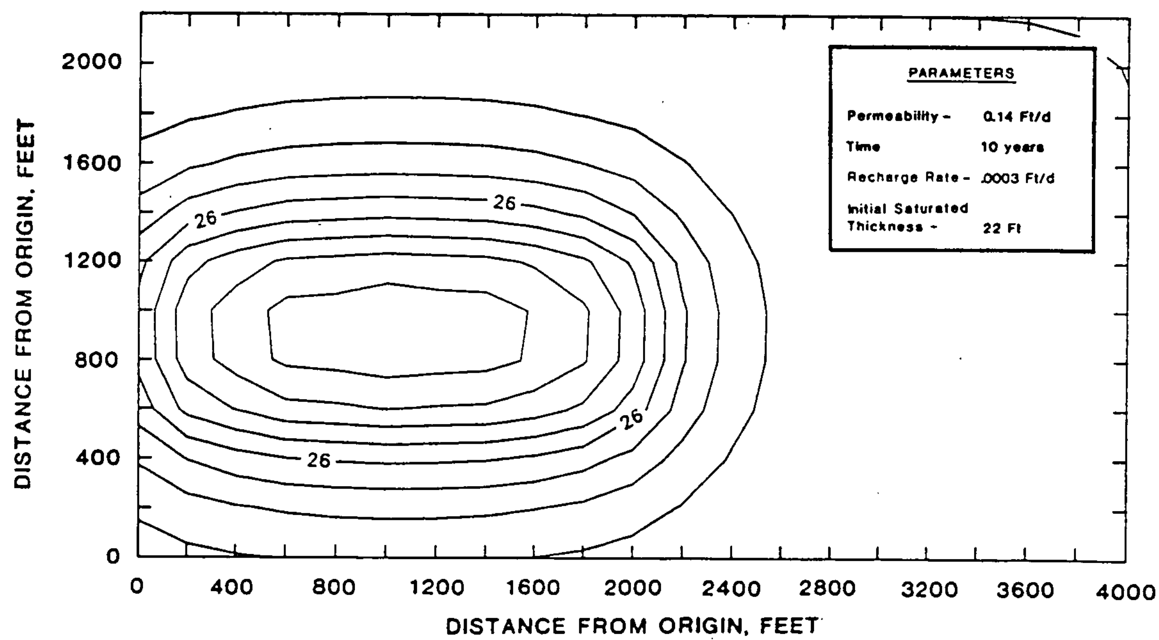
S. S. PAPADOPULOS & ASSOCIATES, INC.
CONSULTING GROUND WATER HYDROLOGISTS

AREA 2 -- CASE 8

FIGURE B-20



a.) Calculated water-table elevation at 10 years



b.) Calculated saturated thickness at 10 years

S. S. PAPADOPULOS & ASSOCIATES, INC. CONSULTING GROUND WATER HYDROLOGISTS	AREA 2 -- CASE 9	FIGURE B-21